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December 1993

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# **Initial Field Trials of the Site Characterization and Analysis Penetrometer System (SCAPS)**

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*by* **Stafford S. Cooper, Donald H. Douglas, Michael K. Sharp,  
Richard A. Olsen, Gregory D. Comes, Philip G. Malone**  
**Geotechnical Laboratory**

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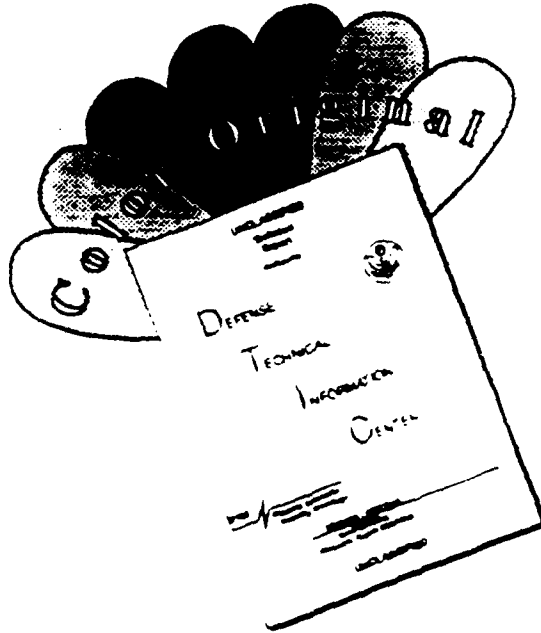
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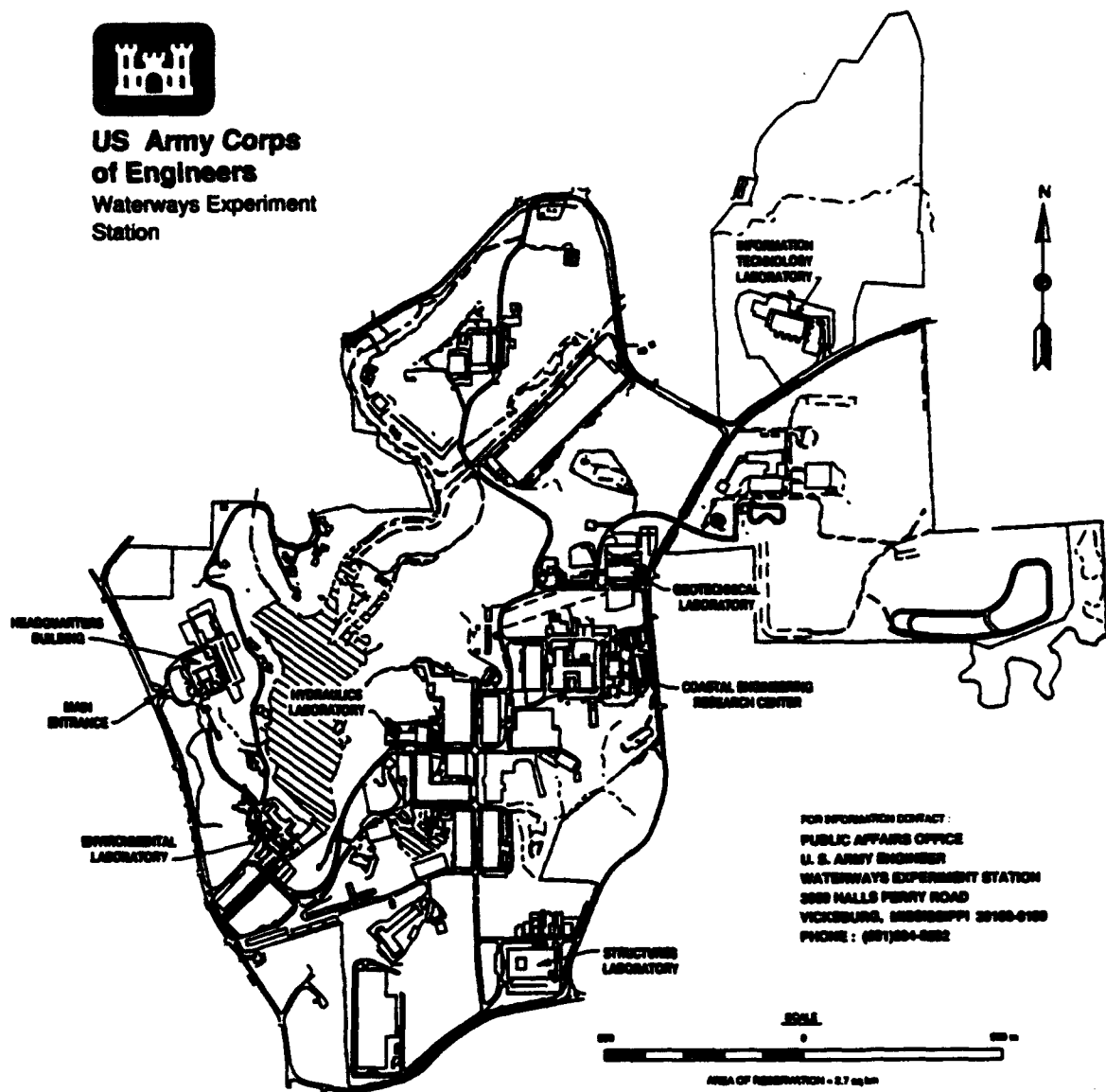
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# Contents

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Preface .....	vi
Summary .....	viii
1—Introduction .....	1
Background .....	1
Purpose .....	3
Scope .....	3
2—Description of Equipment .....	5
Site Mapping Equipment .....	5
Geophysical Survey Equipment .....	6
Penetrometer Screening Equipment .....	6
Penetrometer Sampling Equipment .....	9
Automated Data Acquisition/Processing .....	9
Computerized Site Characterization/Visualization .....	10
3—Activities at the Jacksonville Naval Air Station Test Site .....	11
Site History .....	11
Site Description .....	14
Safety Program .....	14
Geophysical Site Investigation .....	16
Field Testing for Petroleum-Contaminated Soils .....	16
Field Testing for Solvent-Contaminated Soils .....	20
Soil/Fluid Sampling .....	24
Laboratory Testing of Samples .....	25
4—Summary of Results .....	26
Geophysical Survey .....	26
Stratigraphic Assessment .....	26
Field Testing for Petroleum Contamination .....	29
Field Testing for Solvent Contamination .....	29
Sampling and Sample Analysis .....	58
5—Conclusions .....	60
6—Recommendations .....	61
References .....	62

Appendix A: Data from the Penetrometer Unit Equipped with a Soil Strength Measuring System and the Fluorometric Sensor .....	A1
Appendix B: Data from the Penetrometer Unit Equipped with a Soil Strength Measuring System and the Electrical Resistivity Sensor .....	B1
Appendix C: Data from the Chemical Analysis of Soil and Water Samples Collected at the Jacksonville Naval Air Station .....	C1

SF 298

## List of Figures

---

Figure 1. SCAPS penetrometer truck .....	2
Figure 2. Components of the Site Characterization and Analysis Penetrometer System (SCAPS) .....	2
Figure 3. Schematic diagram of the soil fluorometer .....	8
Figure 4. Jacksonville Naval Air Station .....	12
Figure 5. Oil disposal area and solvent disposal area from Gerharty and Miller, Inc. (1980) .....	13
Figure 6. Overall map of test areas .....	15
Figure 7. Outline of grid for geophysical survey of overall site .....	17
Figure 8. Rodamine calibration counts .....	20
Figure 9. Location of penetrometer pushes in both test areas .....	21
Figure 10. Location of penetrometer pushes in Test Area 1 .....	22
Figure 11. Location of penetrometer pushes in Test Area 2 .....	23
Figure 12. Magnetic survey of test areas .....	27
Figure 13. Induced electro-magnetic survey of test areas .....	28
Figure 14. Stratigraphic section for the disposal site .....	31
Figure 15. Soil volume contaminated at over 1,000 ppm DFM equivalent (view looking north) .....	33
Figure 16. Soil volume contaminated at over 1,000 ppm DFM equivalent (view looking east) .....	35
Figure 17. Soil volume contaminated at over 1,000 ppm DFM equivalent (view looking down) .....	37
Figure 18. Soil volume contaminated at over 4,000 ppm DFM equivalent (view looking north) .....	39

Figure 19.	Soil volume contaminated at over 4,000 ppm DFM equivalent (view looking east) . . . . .	41
Figure 20.	Soil volume contaminated at over 4,000 ppm DFM equivalent (view looking down) . . . . .	43
Figure 21.	Soil volume contaminated at over 8,000 ppm DFM equivalent (view looking north) . . . . .	45
Figure 22.	Soil volume contaminated at over 8,000 ppm DFM equivalent (view looking east) . . . . .	47
Figure 23.	Soil volume contaminated at over 8,000 ppm DFM equivalent (view looking down) . . . . .	49
Figure 24.	Soil volume contaminated at over 16,000 ppm DFM equivalent (view looking north) . . . . .	51
Figure 25.	Soil volume contaminated at over 16,000 ppm DFM equivalent (view looking east) . . . . .	53
Figure 26.	Soil volume contaminated at over 16,000 ppm DFM equivalent (view looking down) . . . . .	55
Figure 27.	Plume of oil contamination mapped with drilling and sampling from Geraghty and Miller (1980) . . . . .	57

# Preface

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The work described herein was undertaken by the Earthquake Engineering and Geophysics Division (EEGD), Geotechnical Laboratory (GL), U.S. Army Engineer Waterways Experiment Station (WES), for the Naval Facilities Engineering Command (NAVFAC), Southern Division, under Navcomp Form 2275, Order No. N624679OMP00907, dated 15 March 1990. This report covers the field work done during the period from 16 July 1990 to 14 August 1990 at the Naval Air Station (NAS), Jacksonville, FL. The Project Officer for NAVFAC was Mr. Joel Murphy. Coordination of the field work was done by Mr. Timothy Curtain, Jacksonville NAS.

The investigation was undertaken in part as a field trial of equipment developed in the Site Characterization and Analysis Cone Penetrometer Tri-Services Project directed by the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), now the U.S. Army Environmental Center. Coordination with USATHAMA was provided by Messrs. Paul W. Lurk, Wayne Sisk, and Robert Bartell. Another objective of the work was to provide some initial site screening results of possibly contaminated sites at the Jacksonville NAS to assist them in formulating remediation plans.

Field work was done by Messrs. Stafford S. Cooper, Donald H. Douglas, Michael K. Sharp, Richard A. Olsen, and Karl F. Konecny, EEGD, and Messrs. Henry L. Blake, Eugene A. Graves, and W. Bryant Peterson, Instrumentation Services Division, and Mr. William H. Dulaney, Logistics Office, WES. Assistance in the field work was provided Dr. Stephen A. Lieberman and Mr. Gregory Theriault, Naval Ocean Systems Center.

Report preparation was done by Messrs. Cooper, Douglas, Sharp, Olsen, Gregory D. Comes, and Dr. Philip G. Malone, EEGD. Assistance was provided by Messrs. Ezell Allen, William Megehee, and Melvin Seid, EEGD. Mr. Cooper now works in the Environmental Laboratory, WES, and Dr. Malone works in the Structures Laboratory, WES.

The project was under the direct supervision of Mr. Joseph R. Curro, Jr., Chief, Engineering Geophysics Branch, EEGD, Dr. A. G. Franklin, Chief, EEGD, and Dr. W. F. Marcuson III, Director, GL.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

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# Summary

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At the request of the Naval Facilities Engineering Command (NAVFAC), Southern Division, Charleston, SC, the U.S. Army Engineer Waterways Experiment Station (WES) conducted the initial field trial of the Site Characterization and Analysis Penetrometer System (SCAPS) at Jacksonville Naval Air Station (NAS), Jacksonville, FL. This work was carried out by a field crew consisting of personnel from WES and the Naval Ocean Systems Center (NOSC) during the period 16 July 1990 to 14 August 1990. Funding was provided under NAVCOMP Form 2275, Order No. N6246790MP00907 dated 15 March 1990. Mr. Joel Murphy, Southern Division, NAVFAC, was the project monitor for this work.

The SCAPS investigation at the Jacksonville NAS had two primary objectives: (a) to provide data that could be useful in formulating remediation plans for the facility and (b) to provide for the initial field trial of the SCAPS currently under development by WES for the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), now the U.S. Army Environmental Center. Since the investigation served both contaminant screening and continuing research and development interests, USATHAMA also provided support for this field investigation effort. Messrs. Paul Lurk and Wayne Sisk were USATHAMA project managers during this phase of the SCAPS program.

The original concept for the SCAPS was to develop an integrated site screening characterization system whose capabilities would include (a) surface mapping, (b) geophysical surveys using magnetic, induced electromagnetic, and radar instruments, (c) measurements of soil strength, soil electrical resistivity, and laser-induced soil fluorometry using screening instrumentation mounted in a soil penetrometer, (d) soil and fluid samplers, and (e) computerized data acquisition, interpretation, and visualization. The goal of the SCAPS program is to provide detailed, rapid, and cost-effective surface and subsurface data for input to site assessment/remediation efforts. Although a few system components had been previously field tested, this was the first field deployment of the full SCAPS with its unique fiber optic fluorescence detection tools.

The test areas selected for this work were located on the southern half of the Jacksonville NAS in a closed oil and solvent disposal pits area (site), approximately 300 m west of Mad Fox Drive (1,000 m west of the St. Johns

River) and bounded on the north by Child Street and on the south by Gannet Road. Oily wastes and used solvents had been disposed in this area in the past by pouring the liquids into open pits in the area and covering the pits over as they were filled. It is estimated that 265,000 to 475,000  $\ell$  of waste oil have been buried in the northern part of the area near Childs Street (Test Site 1) and over 3,600  $\ell$  of waste solvents and metal-finishing wastes have been buried in the southern part of the area (Test Site 2).

A geophysical survey was undertaken over the site, and separate measurements were made over the points where penetrometer pushes were planned. The survey systems were used to prevent metallic debris from damaging the instrumentation on the penetrometer. Sweeps were made using a magnetometer and an induced electromagnetic unit. The magnetometer showed primarily metal debris scattered over the area. No distinct pattern that could be related to the location of disposal pits could be found with the magnetometer over either Test Sites 1 or 2. The electromagnetic (E-M) survey (or soil conductivity survey) showed much higher variability over Test Site 1 (90 mhos/m range) than that over Test Site 2 (60 mhos/m range). Local low-conductivity locations were found in Test Site 1 that were approximately in the location of the oil burial pits. Ground-penetrating radar (GPR) was tested over known targets (metal pipe and culvert), but was not routinely employed. After testing with both antenna systems, E-M and magnetometer surveys were judged to be more effective than GPR for this site.

The site investigation was undertaken with a soil penetrometer unit equipped to measure soil strength characteristics and either soil fluorescence or soil electrical resistivity. The soil strength measurements (tip resistance and sleeve friction) were used to determine the soil type. Soil fluorescence was used as an indicator of oil contamination. Soil electrical resistivity (DC resistivity) was used to detect any contaminant that can alter the electrical properties of the soil.

In the course of the investigation, two sites were tested with the fiber optic (36 pushes) and resistivity (10 pushes) screening penetrometer tools. Five soil samples were obtained using a commercially available Mostap soil sampler. One fluid sample was obtained with a commercially developed Hydropunch sampler.

Thirty-four pushes were made at the oil disposal site (Test Site 1) using a laser-induced soil fluorometer. Tests with the unit demonstrated that it could detect the presence of oil at or above a concentration of 500 ppm. Determination of the detection limit was done using sand samples that were spiked with weighed amounts of marine diesel fuel. Estimates of the waste oil concentrations present were obtained by measuring the maximum fluorescence intensity within the spectral region of interest (350 to 550 nm) and calculating the corresponding oil concentration based on the calibration standards prepared from marine diesel fuel and clean sand. Fluorescence in petroleum products is dependent on the exact composition of the product, whether the oil is free or absorbed on the soil, and the soil pH and temperature. Because of the number

of variables that can change the fluorescence response, the soil fluorometer is considered in this study to be a semiquantitative screening tool. Possible interferences from soil matrices and other fluorescing materials in the soil remain to be determined by further field and laboratory testing.

Data from the fluorometer are taken every 1 sec as the penetrometer rod is being advanced at a rate of 2 cm/second. The data obtained were used to produce a three-dimensional visualization of the shape and size of the mass of the contaminated soil. Visualizations were prepared for soil masses that showed increasingly high concentrations of oil. The positions of the highest concentration can be assumed to be the locations of the formerly used disposal pits.

Two pushes with the soil fluorometer were made at Test Site 2. The results showed no detectable fluorescence; the testing was continued at Site 2 with the electrical resistivity tool. Ten pushes were made with the electrical resistivity tool in the area of suspected solvent contamination (Test Site 2). An area of high resistivity was noted in several pushes at a depth of approximately 13 m (43 to 45 ft). A water sample was collected using the Hydropunch sampler and showed that the high resistivity was probably caused by the uncontaminated (clean) water present at this depth in the lower sandy unit at Test Site 2. The resistivity tool could not detect solvent contamination at the low levels (<5 ppm) reported at Test Site 2.

The following conclusions can be drawn from the field testing at the Jacksonville NAS:

- a. The geophysical equipment functioned adequately and allowed the testing to be accomplished without damage to the penetrometer equipment.
- b. The laser surveying equipment provided the resolution necessary for the location of the penetrometer holes.
- c. The fluorometer successfully located the oil contamination at Test Site 1. The limit of detection with the fluorometer (as configured at the Jacksonville NAS) for diesel fuel and related oily waste is approximately 500 ppm.
- d. The soil fluorometer did not respond to solvent contamination in the low levels (<5 ppm) present at Test Site 2.
- e. The DC resistivity tool did not detect any consistent anomalies that could be attributed to solvent contamination at Test Site 2. The most persistent resistivity anomaly occurred at a depth of 13 m (43 to 45 ft). A water sample collected at the depth of the resistivity increase showed that the sand unit at this depth contained uncontaminated water. The very clean water in a sand unit is the cause for the high resistivity observed at the 13-m depth.

- f.* The commercially available soil sampler used performed satisfactorily until it was broken when encountering buried objects at depths below the limits of investigation. Conditions at the NAS test sites required that the water sampler be operated at depths exceeding the manufacturer's recommended maximum depth. The water sampler failed on the first push and was not available for the further sampling.

The field investigation conducted at the Jacksonville NAS has led to the following recommendations for future research:

- a.* The double-fiber fluorometer used at the NAS should become the standard design for future use in detecting hydrocarbons (POL).
- b.* The resistivity sensor should be specifically used when contrast in electrical properties is a major feature in the contaminated subsurface material. Work on a detection system for solvents should be emphasized in future research programs.
- c.* Soil strength measurements should be continued as an integral part of the sensor systems.
- d.* Attempts should be made to obtain more robust water and soil samples either by modifying the commercial unit or preparing a new design.
- e.* Future field efforts should include side-by-side comparison of sensor output and sample analyses so that the response of the sensors can be carefully assessed under a variety of field conditions. Future studies should also be used to address adverse soil matrix effects and interference from other fluorescing compounds that may be present in soil. Such effects could prove troublesome, particularly at low concentrations of contamination.
- f.* A nonhazardous substance should be developed for use in an in situ grouting system that will allow for grouting as the probe is retracted.

# 1 Introduction

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## Background

In 1988, the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), now the U.S. Army Environmental Center, tasked the U.S. Army Engineer Waterways Experiment Station (WES) to accelerate development of a rapid and cost-effective penetrometer system for hazardous waste site soils assessments. In 1989, the project was designated as a Tri-Services (Army, Navy, Air Force) program with USATHAMA as the lead agency and WES as principal developer of a Site Characterization and Analysis Penetrometer System (SCAPS). The objective of the SCAPS development program is to provide equipment and methods that can be used to collect soils characterization data and contaminant screening data onsite so that remediation decisions can be expedited. The truck-mounted SCAPS (Figure 1) provides a basis for this work by combining a rapid mapping capability, geophysical equipment for reconnaissance surveys, penetrometer screening tools or sensor systems for soils characterization and contaminant detection, penetrometer-based samplers, computerized data acquisition, and onsite data processing. Data on soil type and soil contamination are interpreted using a three-dimensional (3-D) visualization program (Interactive Volume Model or IVM), which is used offsite after data are acquired. The program takes soil data and measurements of the level of contamination in soil and produces 3-D gridded data that depicts the contaminated zones as a series of shells or interrelated shapes in the gridded space. The interaction of the components of the SCAPS is shown graphically in Figure 2.

At the time the investigation reported here was undertaken, the SCAPS, although not completed, included innovative software and hardware that required evaluation under realistic field conditions. Among the more important developments to be tested was the first fiber optic fluorometric sensor developed for in situ measurements of fluorescence in soils. Using laser excitation, this sensor system has proven capable of detecting the fluorescence of dyes injected into soil, as well as petroleum, oil, and lubricants mixed in soils in the laboratory (Cooper, Malone, and Lieberman 1990). Since the first version of the truck-mounted SCAPS had recently been assembled and two prototype contaminant sensors had been developed (a resistivity-measuring unit and fiber

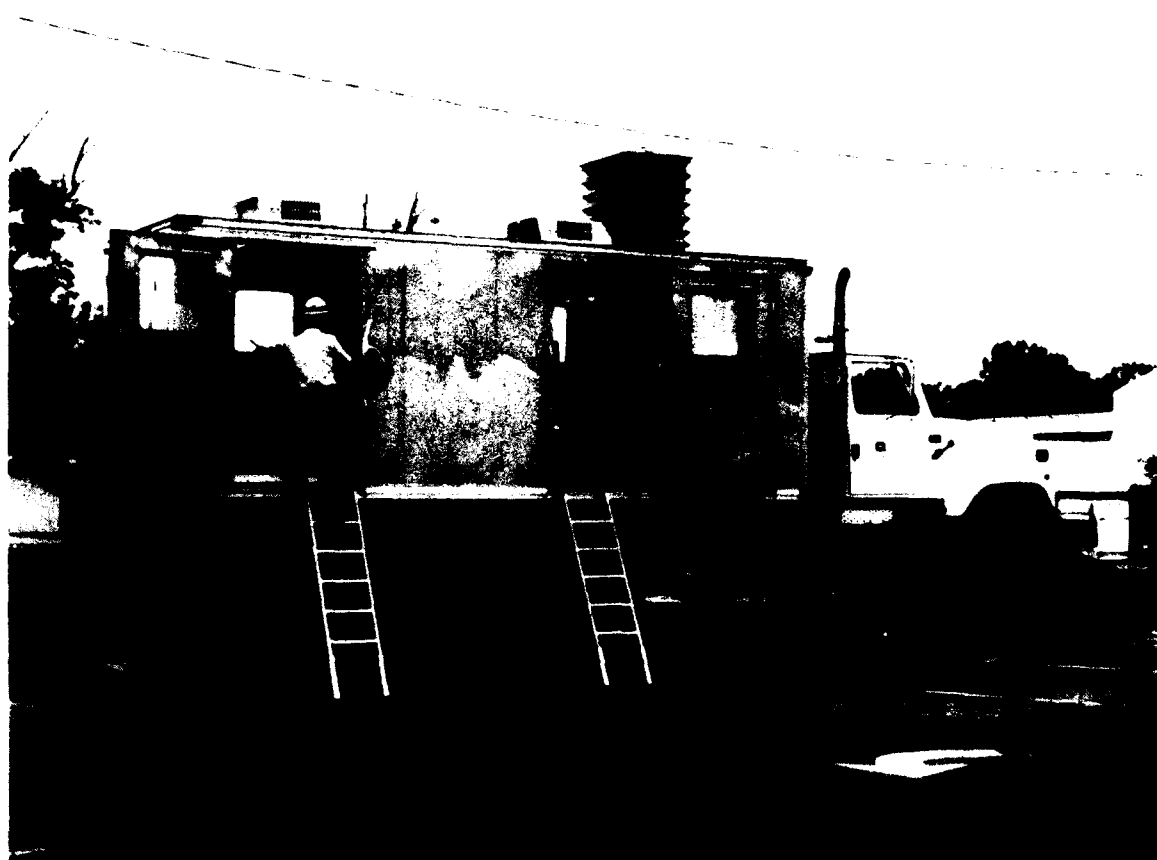


Figure 1. SCAPS penetrometer truck

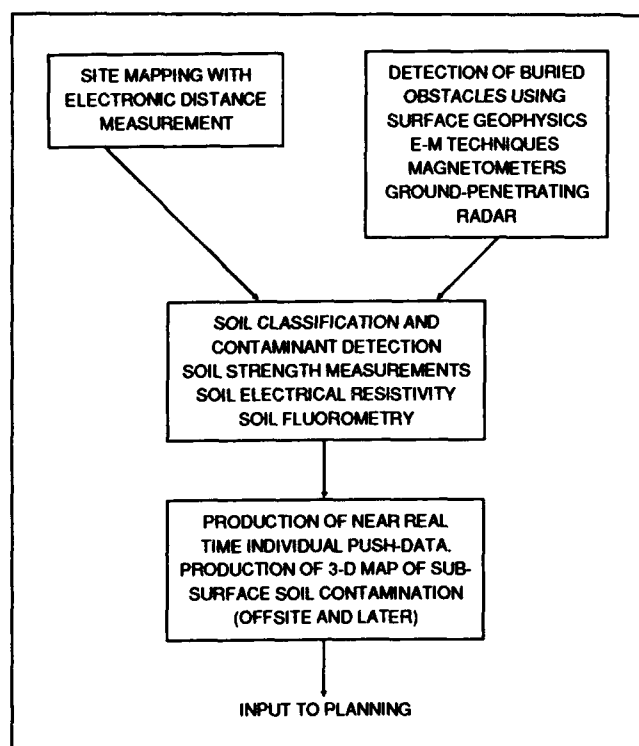


Figure 2. Components of the Site Characterization and Analysis Penetrometer System (SCAPS)

optic soil fluorometer), the decision was made to conduct proof-of-concept field testing of the system.

In discussions with the staff of the Southern Division Naval Facilities Engineering Command, Charleston, SC, Naval Air Station (NAS), Jacksonville, FL, was proposed as a candidate site for the initial field testing of the SCAPS unit. The Jacksonville NAS had several potentially useful test areas including a closed oil disposal site and a closed solvent disposal area.

The closed disposal sites were intensively studied to control the movement of petroleum, oil, and lubricant (POL) wastes. Additional remediation studies are underway. The sites allowed the field evaluation of the SCAPS unit with relatively low exposure risks to the personnel and equipment. Information developed with the SCAPS equipment can be used as input to remediation planning.

## **Purpose**

The purpose of this field exercise was to evaluate all of the components and software developed for the SCAPS system at a documented field site where known contamination was present. The goal of the field exercise was to compare the site screening data available from SCAPS with data obtained from conventional site investigation results. The field exercise was also an opportunity for assembling new configurations of the equipment as difficulties were observed in the existing setup. The field operations consisted of testing, modification, and additional testing to optimize the penetrometer unit and to evaluate the visualization system.

## **Scope**

Geophysical survey techniques (magnetometer, induced electromagnetic measurements, and ground-penetrating radar) were used to scan the area for buried metal objects that would be obstacles for the penetrometer and to look for patterns of disturbed ground that would indicate the location of burial pits. In the process of surveying, the usefulness of each survey technique was evaluated.

The field exercise reported here involved using the soil stratigraphic characterization capabilities of the SCAPS at both an oil disposal site and a solvent disposal site. The resistivity sensor was tested primarily in the solvent disposal area. The soil fluorometer was used to map oil contamination at the oil disposal area.

The data collected on the site were displayed as profiles and partly analyzed onsite. The results from the oil contamination mapping were further analyzed after the field work was complete by using a computer visualization system.

The visualization system contours the concentrations of the contaminant of interest and allows changes in the contouring parameters (interaction of the data points) and addition of extended data sets as they are developed.

The initial field testing of the SCAPS unit was undertaken at a well-documented site where soil contamination investigations are continuing in order to have comparative data on the extent of soil contamination that had been collected prior to this field investigation using conventional approaches such as drilling, sampling, and analysis of samples. The field investigation did not include extensive comparative sampling and testing to develop a sample-by-sample comparison of sensor output and laboratory analyses. Only five soil samples were analyzed to assist in interpreting data from the fluorometric sensor. Two soil samples and one water sample were collected from the area where the resistivity sensor had been used. The sampling effort provided the basis for an evaluation of the penetrometer-based soil and water samplers.

## **2 Description of Equipment**

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The SCAPS includes a suite of surface geophysical equipment, survey and mapping equipment, special penetrometers with sensors for contaminant detection, and soil and pore fluid penetrometer samplers. The SCAPS system is mounted in a uniquely engineered truck designed with protected work spaces to allow access to toxic and hazardous sites while minimizing exposure of the work crew. The SCAPS screening penetrometers are equipped with sensors that can determine physical and chemical characteristics of the soil as the penetrometer tip is forced through the soil. The SCAPS includes sensors that can determine the strength, electrical resistivity, and spectral properties—in this case, the fluorescence of soils. All sensors read out in real time, and a computer-based data collection and analysis system permits a display and partial interpretation of data in the instrument compartment on the penetrometer truck. The data analysis system also allows processing of various types of surface geophysical and mapping data collected onsite and integration of data into a unified database. Fluid and soil samples can be collected using devices such as the "Hydropunch" and the Mostap soil sampler that are designed for use with penetrometers. The SCAPS system is also equipped to seal each penetrometer hole with grout as the geotechnical investigation proceeds across a site. However, tremie grouting with a cement-bentonite mixture was used at this site because of concerns about the toxicity of the only two-component polymer grout formulation available at the time. SCAPS is designed to save time and costs and to minimize exposure of the crew while sensor data or samples are collected. The SCAPS unit is built so that surfaces and compartments exposed to waste can be thoroughly and completely decontaminated. No penetrometer units available in the private sector have this combination of capabilities.

### **Site Mapping Equipment**

The location of penetrometer push points and the layout of the geophysical survey stations is done using a Total Station Electronic Distance Measuring (EDM) System. The site mapping work at the Jacksonville NAS was done with a Topcon EDM unit equipped with a Leitz Electronic Notebook. The electronic notebook was read into an HP Vectra computer in the penetrometer truck, and preliminary processing was done in the field. The final site maps

were generated at WES using an AutoCad version on an Intergraph Microstation.

## **Geophysical Survey Equipment**

A geophysical site survey was undertaken primarily to determine if there was metallic debris in the area where the penetrometer unit would be operating. A secondary objective was to determine if there was any geophysical evidence of burial pits that had been reported to have been used for oil disposal. Three different geophysical techniques were evaluated on the Jacksonville NAS site. Total magnetic field intensity was measured using an EDA OMNI IV Magnetometer System. Soil conductivity was determined with Geonics EM-31 Terrain Conductivity System run in a configuration that measured the quadrature-phase component—that part of the EM signal that is most sensitive to changes in earth conductivity. A ground-probing radar (GSSI model 4800 GPR) was evaluated at several locations where known targets such as utility pipes or culverts were present.

## **Penetrometer Screening Equipment**

The major component of the SCAPS system is a 20-ton (18,143-lb), all-wheel-drive truck that was designed specifically for operations at hazardous waste sites. The truck carries a hydraulic power unit and controls to operate the push apparatus, a power takeoff-driven 25-kw generator, dual air conditioning units, separated push and data acquisition work spaces, a shock-isolated floor for the electronics package, easily decontaminated stainless steel van body, and numerous other personnel protection features. A specially designed trailer is used to carry the grouting pumps, water tank, and a closed loop steam cleaner to clean the penetrometer rods and tools as they are withdrawn from the soil.

The electronics package includes WES-designed and built signal-conditioning hardware and test equipment capable of providing onsite calibrations of contaminant detectors and load cells used to measure the force required to overcome soil penetration resistance.

Data acquisition and initial data processing are carried out with an HP Vectra 25 Mhz computer, and a matching computer is used for data management and file integration. The second computer affords redundancy in the event of a computer failure. Postprocessing of the data to provide a 3-D visualization of site conditions is presently done with a computer work station that can be used at WES or brought to the installation.

The use of the soil strength measurements (cone tip and sleeve friction) made with the cone penetrometer to determine soil type has been well-documented (Campanella and Roberts 1982; Olsen 1988; Olsen and Farr

1986). The design of the equipment and the interpretation technique used in this study have been described in Cooper et al. (1988).

The soil electrical (DC) resistivity measurements were made using equipment similar to that described in Cooper et al. (1988). Calibration and operation followed standard practices described in detail in this same reference.

The soil fluorometer was adapted from a design developed by Lieberman, Inman, and Theriault (1989) for use in measuring fluorescence in seawater. A schematic of the system is presented in Figure 3. In making a measurement, the exciting radiation is produced by firing a pulsed nitrogen laser (emitting at 337 nm). The laser light is separated with a beam splitter, and a part of the pulse is used to start the timing circuit for the detector. The major part of the pulse is directed into a 250- $\mu$ m optical fiber by passing it through a 3-mm-diam hole in the backside of a mirror oriented at 45 deg to the path of the beam. The exciting radiation passes down the fiber that runs through the center of the penetrometer rod. The fiber ends at a 6.35-mm sapphire window that passes the light onto the soil surface adjacent to the window. The fluorescence signal is collected by the same fiber and returned to the mirror and optically coupled to the polychromator. The dispersed energy is measured using a linear photodiode array and an optical multichannel analyzer. This system is much faster than the traditional scanning spectro-fluorometers. Readout of an entire emission spectrum requires only 15 msec. The rapidity of the readout makes it practical to "stack" or add successive pulses and increase the sensitivity of the unit.

An improved version of the fiber optic fluorometer became available while the penetrometer unit was at the Jacksonville NAS. The new system involved changing the single-fiber cable to use a newly developed two-fiber cable and eliminating one mirror. The parts were brought into the field and the fluorometer was modified on the spot. The new unit was aligned and calibrated and data collection continued. The two-fiber fluorometer operated in the same way as the single-fiber system described above, but required less attention to alignment and provided greater sensitivity.

The soil fluorometer employing the nitrogen laser excitation source was run with a variety of standards prepared from clay and sand matrices. In this case, the typical limit for the detection of fresh diesel fuel is 500 ppm by weight in soil. Initial work indicates the moisture content of the solid has little effect on the fluorescence response. The response of the fluorometer is directly related to the concentration of aromatic compounds in the hydrocarbon fuel.

The fluorescence data available from the soil probe presents unique problems in data reduction and interpretation. Each fluorescence spectrum consists of intensities measured at 1,024 points for every 2-cm (0.8-in.) layer of soil investigated. A fully operational soil probe (or penetrometer) has the potential to investigate a total of 210 m (700 ft.) of soil in a single day. This amount of data can make interpretation slow. The present data processing system records all spectral intensity measurements and makes corrections for standards and for

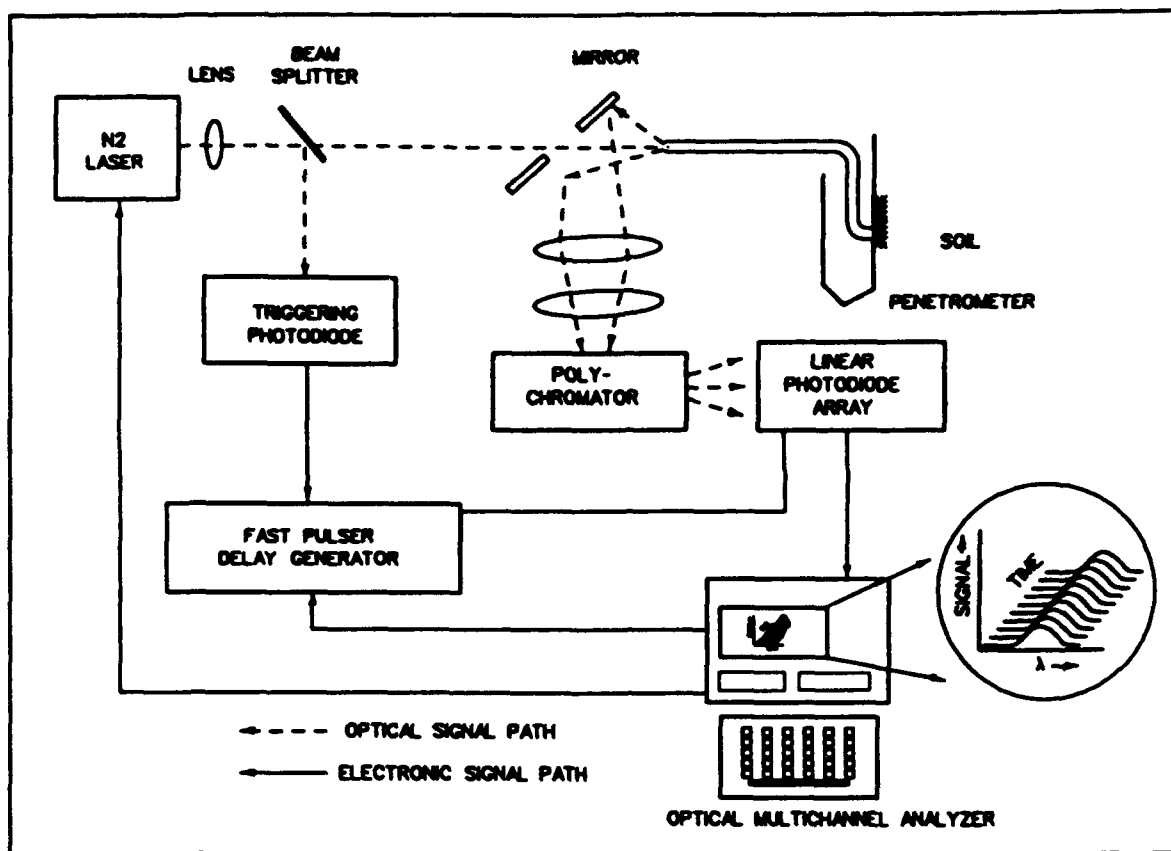


Figure 3. Schematic diagram of the soil fluorometer

instrument drift during measurement. The corrected data are screened to develop the photon counts for the peak of interest and the background. The peak height is then compared with a calibration curve prepared with the contaminant in a soil matrix similar to that found on the site being investigated. A file showing the estimated contaminant concentration, the map coordinates, and the depth below a surveyed datum is prepared from the spectral data. The final data file is transformed into a 3-D gridded file and is plotted using a visualization program.

The soil fluorometer system has wide application in the delineation of contaminated soil produced by leaks or spills of diesel fuel, gasoline, and other POL products. Although most chemical compounds used in industry do not fluoresce, those that do are also relatively common constituents in industrial-grade solvents and degreasers. Optical brighteners that are being commonly incorporated in cleaners and detergents can also provide a fluorescing tracer for wastewater.

The Jacksonville NAS site has relatively high concentrations of heavy-bodied long chain hydrocarbons that were readily detected by the SCAPS laser system as currently configured; however, more field and laboratory testing are

needed to assess the effect of soil matrices and possible interference from other fluorescent materials that may be present in soil.

## **Penetrometer Sampling Equipment**

At present, SCAPS is using commercially available samplers for collecting groundwater and soil samples. Groundwater sampling was attempted with a Hydropunch Sampler (QED Inc., Ann Arbor, MI). The Hydropunch sampler mounts on the end of the penetrometer push rod and can be used to obtain a groundwater sample of approximately 200-ml volume. The maximum sample depth is determined by the strength and type of soil through which the sampler is pushed. The maximum load that can be put on the sampler during a sampling push is approximately 67 MPa (700 tsf). The maximum depth proved to be approximately 15 m (45 ft).

The Mostap Sampler (A. P. Van der Berg, Netherlands) used was a "stab-type" sampler designed to collect a soil core that was 35 mm in diameter and up to 1 m (3.03 ft) long. The sampler mounts on the end of the conventional penetrometer push rod. The maximum depth for sampling is estimated by the manufacturer to be approximately 60 m (196 ft). The practical depth of sampling depends on the strength and the type of soil and the presence of buried items in the soil that can damage the samplers. Both units were tested to near or beyond their structural limits, which resulted in structural failures.

## **Automated Data Acquisition/Processing**

The data acquisition system and the postprocessing system each have a separate computer in control. The two computers are linked with a token network so that data can be exchanged during and after the penetration testing.

The data acquisition computer controls all systems and stores all the data on a demountable hard disk during the penetration test. The major block of data is generated by the soil fluorometer system in the optical multichannel analyzer (OMA). The OMA is a separate computer that is controlled by the data acquisition computer through a general purpose interface bus. The data acquisition is also interfaced directly with the amplifier/filter components for the measurement of strain on the cone tip and sleeve, amplifiers for the electrical resistivity measurements, a variable potentiometer that reads out the position of the hydraulic rams (data used to calculate the depth of the penetrometer tip), and the computer token network.

The postprocessing computer can exchange data with the data acquisition computer using the token network during and after a penetration test. The postprocessing computer can be used while the data acquisition computer is acquiring data for file editing, individual penetration test plotting, pollution

plume plotting, interfacing with the survey field notebook equipment, site plan plotting, or project documentation.

## **Computerized Site Characterization/Visualization**

The SCAPS unit has the potential to investigate approximately 210 m (700 ft.) of soil per day, although the SCAPS has not met that potential yet. This level of activity can generate a massive amount of data on the variation of point resistance, sleeve friction, soil electrical resistance, and soil fluorescence. Measurements are typically made at 2-cm (0.8-in.) intervals. Currently, penetrometer data are being interpreted using 3-D visualization performed using Interactive Volume Modeler (IVM) software developed by Dynamic Graphics, Inc. (Alameda, CA) on a Silicon Graphics (Mt. View, CA) workstation. The IVM accepts scattered data file in ASCII format and creates a uniform 3-D grid. Smooth extrapolation and interpretation for points is used to create grid values within and near the existing data. A lateral clipping plane is created to clip extrapolated data outside the bounds of the original data. The basic data controls the location of each known value, but the aspect of the final 3-D shapes produced from a data set can be altered by varying the spacing on the 3-D grid derived from the original data. Typically, the spacing values for the derived grid are selected by examining 3-D volume plots and observing which spacing combination produces a plot that most closely agrees with the original data points.

### **3 Activities at the Jacksonville Naval Air Station Test Site**

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#### **Site History**

Jacksonville NAS is located south of Jacksonville, in Duval County, Florida (Figure 4). This report summarizes an investigation undertaken at a waste and solvent disposal area approximately 1,000 m west of the St. Johns River. There are two documented closed oil pits (Sites No. 1 and 3 in Figure 5) and one solvent disposal pit (Site No. 2 in Figure 5). The general area northeast and southwest of Childs Road has been used as a disposal area for several decades. Wastes dumped in the disposal area included spent lubricating oil, residues from the paint shops, solvents, cold-carbon remover, and other waste liquids and residues (Geraghty and Miller, Inc. 1980). Most of the waste disposal activities for the shops and maintenance areas involved burying the materials in the three disposal areas. Disposal procedures involved digging trenches and pits and pouring the waste directly into the pits. Records indicate drummed wastes were not a major component of the disposed materials.

In a report prepared in 1980, investigators noted that depressions indicating former disposal pits could be found both northeast and southwest of Childs Road (Geraghty and Miller, Inc. 1980). Borings made in the area east and west of Childs Road indicated oil was present floating on the groundwater. Borings that showed floating products also had dissolved oil in water through the entire thickness of the boring (0.6 to 0.8 m). In 33 borings and wells, the oil floating on the water table averaged 4 cm (1.5 in.). In other borings, the oil was an emulsion and no distinct layer was present. The report estimated that the quantity of waste oil on the site was 265,000 to 475,000 l (70,000 to 125,000 gal).

The waste disposal site also received a wide variety of organic solvents. The primary pits for disposal of organic solvents in the test area are labeled as Site 2 in Figure 5. This area received a large volume of used degreasing and paint-stripping solvents. The compounds present in the solvent and strippers were as follows:

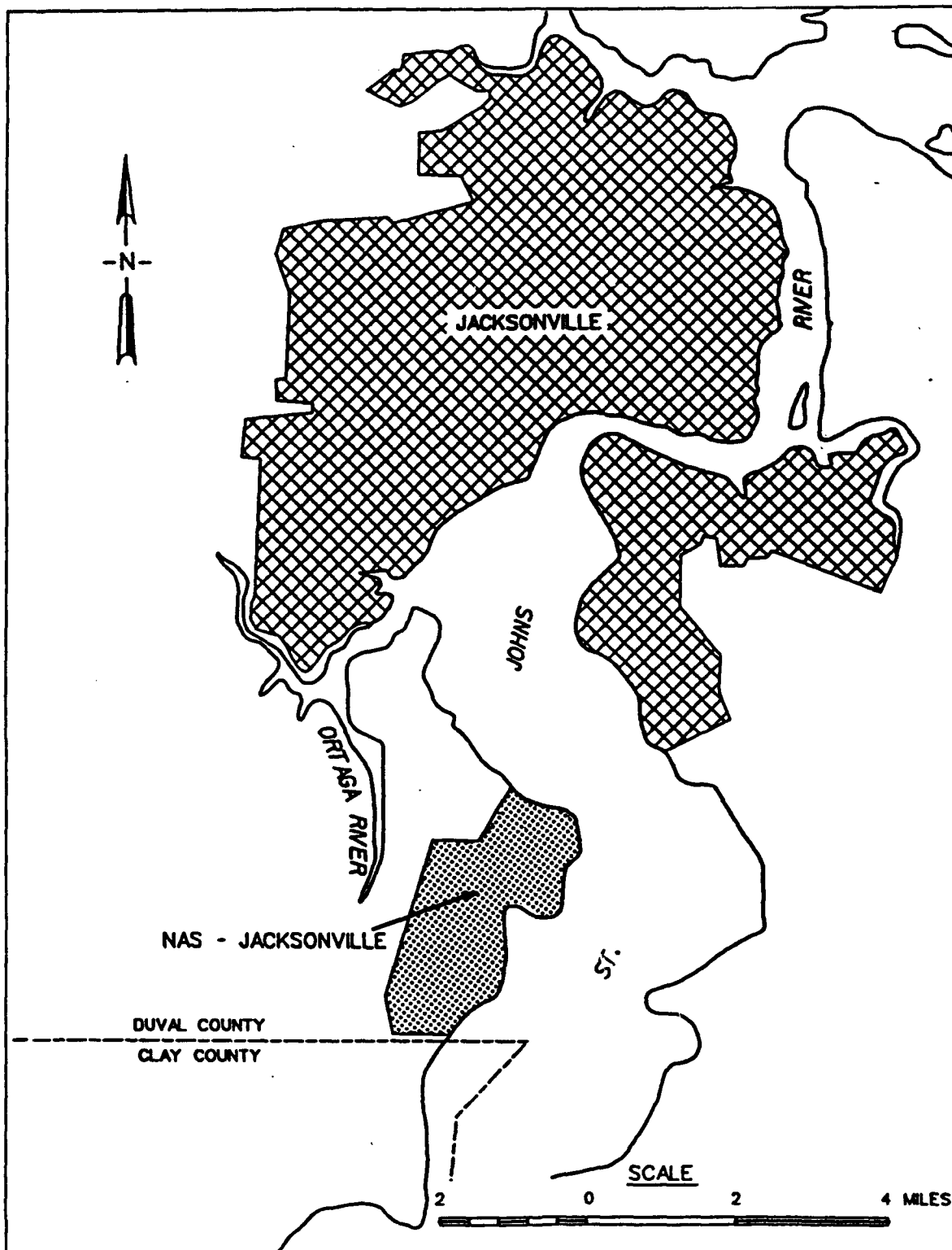


Figure 4. Jacksonville Naval Air Station

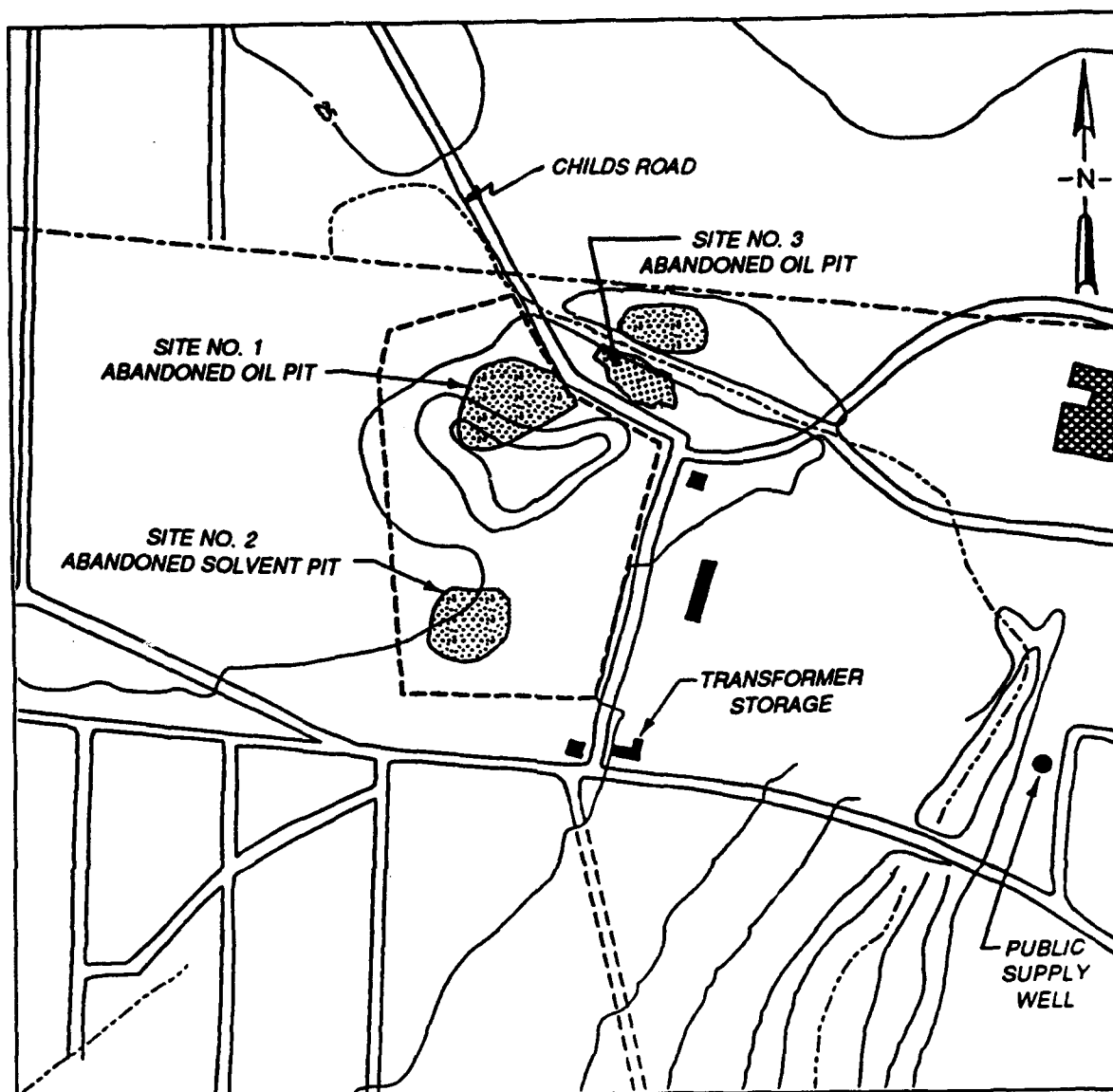


Figure 5. Oil disposal area and solvent disposal area from Gerharty and Miller, Inc. (1980)

methylene chloride  
 methylethyl ketone  
 ethyl acetate  
 trichloroethylene  
 methyl isobutyl ketone  
 n-butyl acetate  
 xylene

The ketones and methylene chloride are ingredients in the paint stripper; tri-chloroethylene and methylene chloride are major constituents in the degreaser. The acetates and xylene are associated with paint stripper and lacquer solvents. Past activity records indicate that 800  $\ell$  (200 gal) per week of cold carbon

cleaner, 1,200 l (300 gal) of used degreaser, and 2,400 l (600 gal) of paint stripper per week were disposed on the site for several decades.

In the 1980 study, only four compounds suspected of being dumped in the disposal site were found. These were as follows:

methylethyl ketone	(188 ppb)
trichloroethylene	(62 ppb)
methyl isobutyl ketone	(40 ppb)
xylene	(120 ppb)

The disposal of paint-stripping waste also produced the possibility of contamination of the groundwater with heavy metals. Groundwater samples across the area were analyzed for heavy metals. Metal levels above the U.S. Environmental Protection Agency (EPA) Interim Drinking Water Standards were found in wells along the west side of the test site and in the plume areas northeast and southwest of Childs Road. The high levels of metal contaminants in the waste oil dumped at the site may account for the heavy metal contamination noted. The highest concentrations observed were as follows:

cadmium	(67 ppb)
chromium	(588 ppb)
lead	(1,324 ppb)
mercury	(7.2 ppb)

## Site Description

The test site can be characterized as an open grassy field with occasional stands of trees, mostly flat, with maximum site relief on the order of 0.3 to 1 m (1 to 3 ft). Access to most test locations on the site was good to excellent, and no trafficability problems (mud, etc.) were encountered, even in wet weather. A map of the site is shown in Figure 6.

## Safety Program

The safety plan for operations at the oil and volatile products disposal pits was developed after a review of the past work at the test site and consultation with the NAS. The major hazard at the site consisted of fuel and diluted chlorinated solvents. The crew was equipped to operate with Level C personal protective equipment inside and outside the penetrometer truck. After arrival on the site and after site surveillance, the decision was made to move to Level D personal protection equipment. As a precaution against any exposure problems, Level C equipment, especially respirators and chemical-resistant coveralls, were maintained within easy reach of personnel in the penetrometer

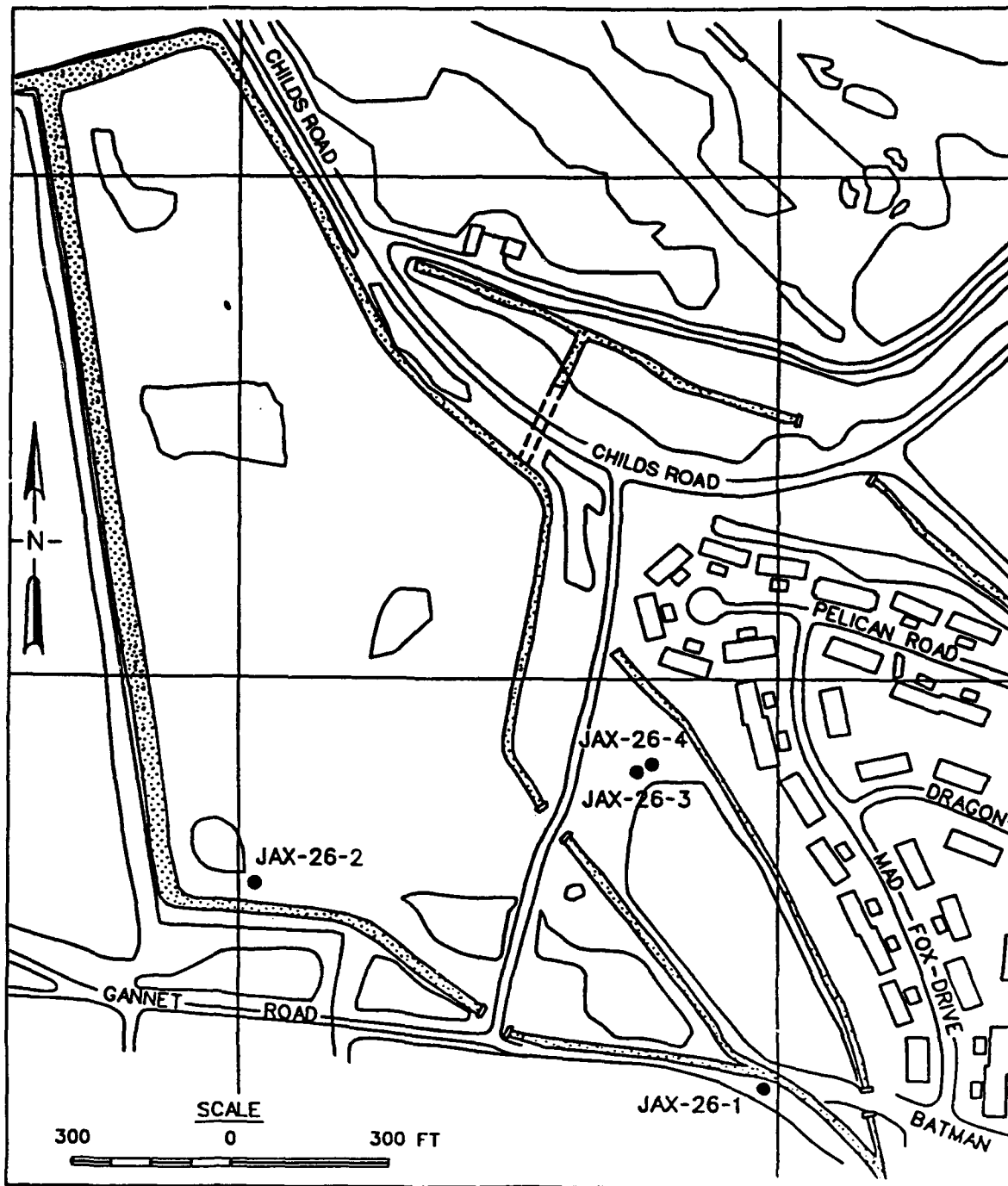


Figure 6. Overall map of test areas

truck. Additionally, chemical-resistant gloves were worn, and escape masks were kept available in the truck.

A separate laser safety plan was developed for use by personnel operating the nitrogen laser used for fluorescence excitation and the helium-neon alignment laser. This plan called for safety goggles and power interlocks on the

laser equipment, as well as restricting access to the instrumentation compartment during laser operation.

The atmosphere in the truck was monitored intermittently using a Foxboro Organic Vapor Analyzer (OVA). The OVA was also used to monitor for the presence of volatile organic solvents on the penetrometer rods as they were withdrawn from the soil and any gases issuing from the penetrometer hole.

## **Geophysical Site Investigation**

A grid was established covering the areas where station records indicated the disposal activity had taken place. The layout used is shown in Figure 7. The "north-south" grid lines were laid out on a bearing of 15 deg west of true north to accommodate the irregular shape of the survey area. The stations on the grid were on 14.4-m (50-ft) centers. The geophysical measurement stations were identified with plastic (nonmagnetic) markers. The area in the immediate vicinity of Childs Road and the area east of Childs Road were not included in the survey grid because the utility lines associated with the road right-of-way provided false anomalies and concealed any anomalies caused by waste disposal activities.

Magnetic measurements were taken throughout the grid to locate metal debris on the site. The magnetic survey was made using a "looping procedure" where one point was established as the base, and the base station was reoccupied at approximately 30-min intervals. The repeated measurements at the base station were used to correct for any drift in the earth's magnetic field.

The EM-31 system was used to take conductivity measurements at all survey points. The unit was operated with the transmitter and receiver poles oriented vertically to give the maximum depth of investigation.

The ground-penetrating radar (GPR) unit was tested over known targets (metal pipe and culvert). Both the 300-Hz antenna and the 100-Hz antenna were run on a trial basis. However, neither antenna used produced satisfactory results against these known targets, and the GPR was not used in the general survey of the test site.

## **Field Testing for Petroleum-Contaminated Soils**

The fluorometric sensor presented some unusual problems in calibration in that the fluorescence peak measured in the waste oil/soil samples found at Site 1 occurred in a broad area between 350 and 550 nm. The fluorometry unit was set up to search the area from 350 to 550 nm in 0.2-nm increments and to present the maximum count for any single channel (0.2-nm bandwidth) in that interval. This procedure was necessary because of the wide variety of

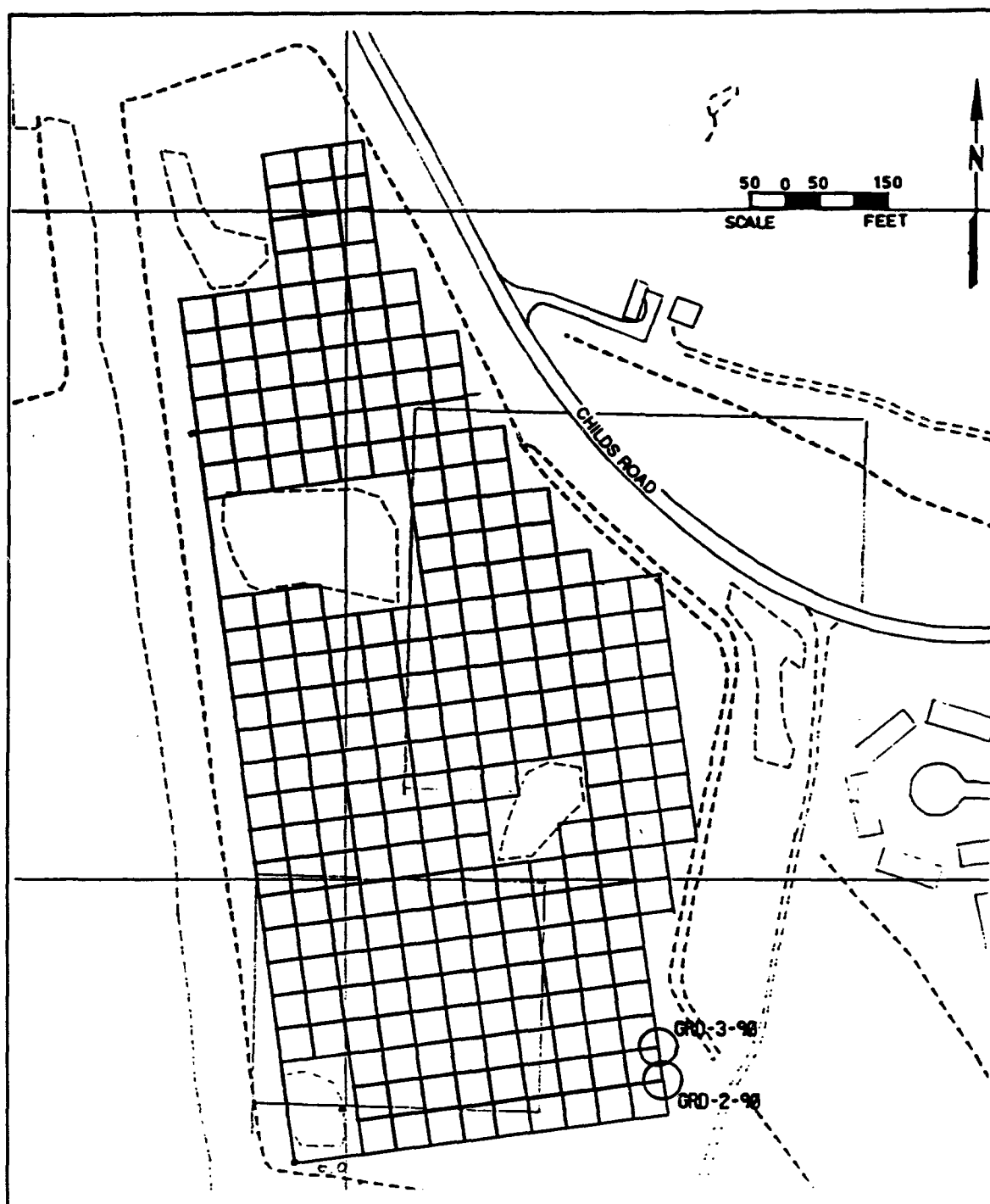


Figure 7. Outline of grid for geophysical survey of overall site

aromatic compounds in the waste oil mixture present in the soil. The different compounds fluoresced at different wavelengths, and not every compound was abundant or even present in every soil sample examined. In order to present the data with some reference to its origin (a petroleum product), standards were made up using weighed amounts of clean diesel fuel in sand. It was recognized early in the development of the SCAPS laser induced fluorescence (LIF) system that some means of intersystem verification would be a necessary requirement. This was due to the inherent variability of optical systems and the need to relate optical system performance to some known and easily verifiable standard. Hence, the need emerged to develop and adapt a 10 micro molar solution of rhodamine dye as a within-system verification standard (Figure 8). In this way, the standard rhodamine solution could be used in a sealed cuvette to monitor the optical system performance over time and to account for the variability of fluorescence counts among tools of varying sensitivity since it was expected that there would be subtle variations in the optical performance of each LIF tool as a result of manufacturing and optical path tolerances. In this way, within-system variations could be compensated for and reasonable variations in sensitivity on a single system output could be related (normalized) to a common standard over time or account for variability in performance among tools (manufactured at different times and to differing specifications). For example, the maximum output of any serially numbered LIF tool could be related to a common calibration standard, and the comparison of maximum calibration counts to a measured count could be used to calculate concentration, even among tools with wide variations in optical performance. Also, this procedure could be used to evaluate system performance changes (for example, to identify a subtle or dramatic change in overall performance of a given tool with time and/or damage incurred during penetration). This approach would provide a powerful diagnostic control in the event of either gradual or catastrophic system degradation and was viewed as an essential step.

Next, it was understood that with a wide variety of possible POL wastes, it was unlikely that any single calibration procedure could prove to be clinically accurate in a comparison of POL concentration based on fluorescence measurements with laboratory analytic procedures based on tests of specific sample. For example, the fluorescence measurements are a relative index of fluorescence over a 1-in. or less depth interval, whereas the laboratory test makes use of a homogenized sample of sufficient volume to satisfy an arbitrary standard. Extreme care must be taken to relate the in situ LIF method to any laboratory test method for oil and grease (O & G), total recoverable petroleum hydrocarbons, or other standard laboratory procedures. However, if the LIF procedure is intended to provide a relative measure of concentration, then it satisfies its primary role as a screening tool. The essence of its worth is that it can indicate areas where further testing (via laboratory accepted regulatory methodology) is required to define the final answer as opposed to testing everything in a 3-D soil matrix in hopes of defining the problem. For more than 50 years, the oil industry has made use of screening methods to identify potential zones of interest for further investigation, rather than using an arbitrarily decided, closely spaced sampling technique as a cost-effective means to provide the

needed information. The screening method approach, governed basically by proven results and economics, is advocated here and is the preferred methodology for large-scale investigations in terms of either depth or areal extent or both. In this scenario, concentrating effort where it is needed is preferred over any "scatter" methodology that may be exquisitely accurate but is also inherently haphazard and unsystematic since it does not rely on the detailed knowledge of in situ conditions that the penetrometer routinely provides.

The fluorometric sensor was calibrated prior to use by filling a test cell fitted over the detector window with clean sand thoroughly mixed with a carefully weighed amount of clean diesel fuel (marine). The test cell was designed to provide infinite thickness for the exciting ultraviolet radiation. The diesel fuel/sand samples were prepared in the laboratory at the Naval Ocean Systems Center from cleaned, dried Ottawa sand and fresh marine diesel fuel and brought to the field in sealed containers. Calibration samples were used only once and discarded after use because of the volatility of the fuel. Calibration curves were prepared by measuring the maximum fluorescence (in counts) of the diesel fuel/sand sample and plotting the count against the concentration of the diesel fuel (in ppm by weight). The maximum fluorescence of the diesel fuel occurred consistently at 440 nm. The data are presented as the equivalent concentration of diesel fuel (marine) or DFM that would produce the same intensity of fluorescence.

Field testing began with several resistivity and fiber optic trial pushes in close proximity to the ditch (north center, Test Area 1). The intent of the trial pushes was to see if the equipment could detect the relatively high concentration of POL known to exist at the location from visible oil seepage into the ditch. The trials were successful in that both the resistivity and the fiber optic systems registered strong anomalous responses at depths (3 to 4.5 m) and locations that were consistent with the visible POL seepage into the ditch. Samples dug from the POL seepage zones in the walls of the ditch were also held against the fiber optic sensor port, with the tool at the surface; these samples showed spectral responses that were virtually identical to the anomalies measured during the pushes. Surface samples of clean sand taken from Area 1 and at other locations on the station were similarly tested and showed no spectral anomalies. The good agreement among resistivity and fiber optic observations and the spectral correlation with contaminated samples were indications that the resistivity and fiber optic tools were capable of detecting moderate to high POL concentrations in situ at this site. This was an important determination. The fiber optic sensor had been bench tested in the laboratory only against available fresh petroleum products, whereas the petroleum contaminants at this site had been in the soil for 5 to 20 years at least. In addition, there was no database available to predict fluorescence variation as a function of product aging, mixing of hydrocarbon products, or changes in situ. In view of these uncertainties, the initial results were most encouraging, and the decision was made to continue field testing. The locations of Test Areas 1 and 2 are shown in Figure 9.

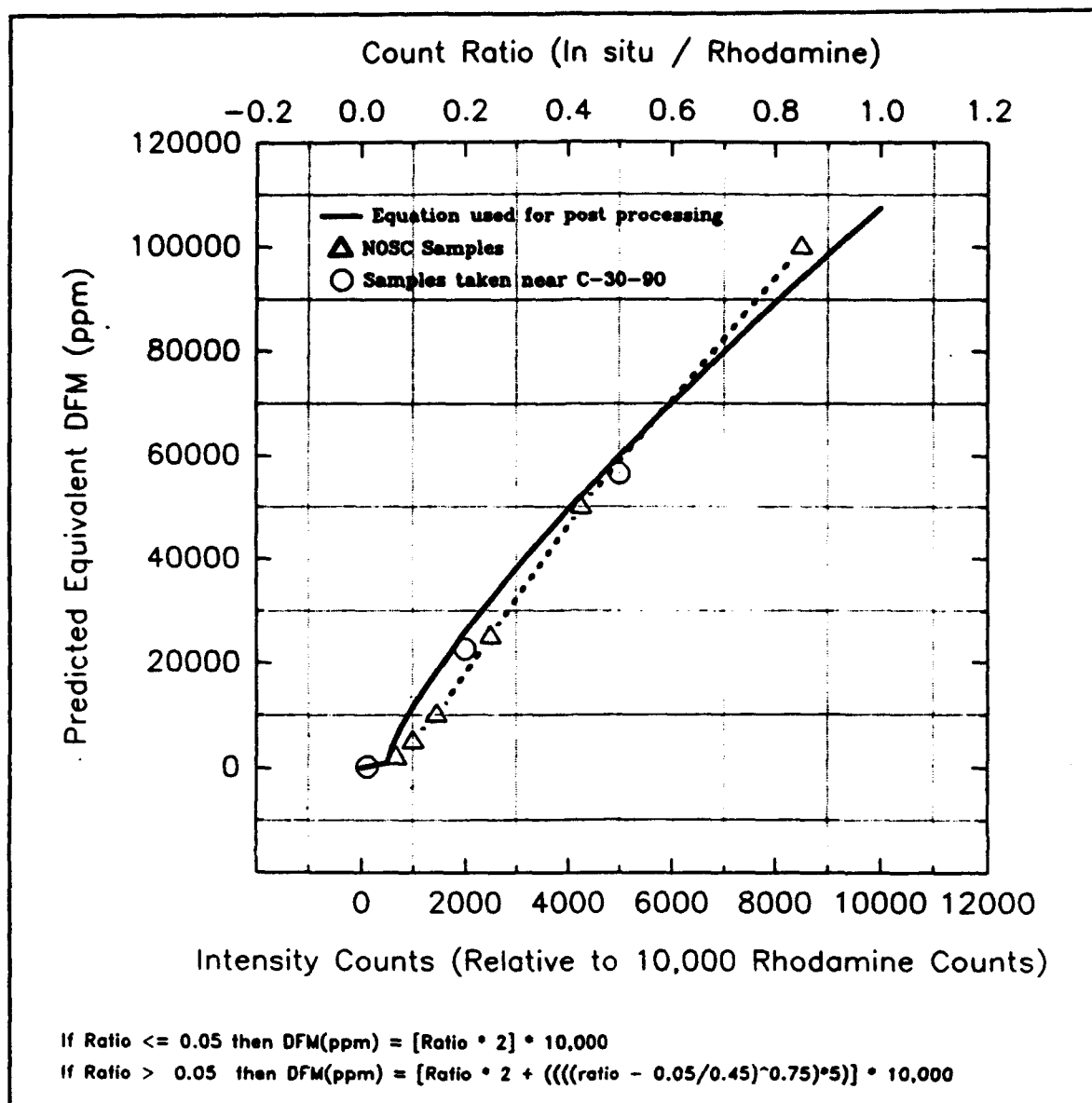


Figure 8. Rhodamine calibration counts

Locations of 34 fiber optic and resistivity screening tool test pushes completed in Area 1 (POL-contaminated area) are shown in Figure 10. The investigation in Area 1 was continued as an exploration to delineate the POL plume boundaries to the limit of detection provided by the tools used.

## Field Testing for Solvent-Contaminated Soils

Area 2, shown in Figure 11, is a closed solvents dumping area. The major contaminants of interest are trichloroethylene and methylene chloride, which are known to have been extensively used as a solvent in cleaning operations at

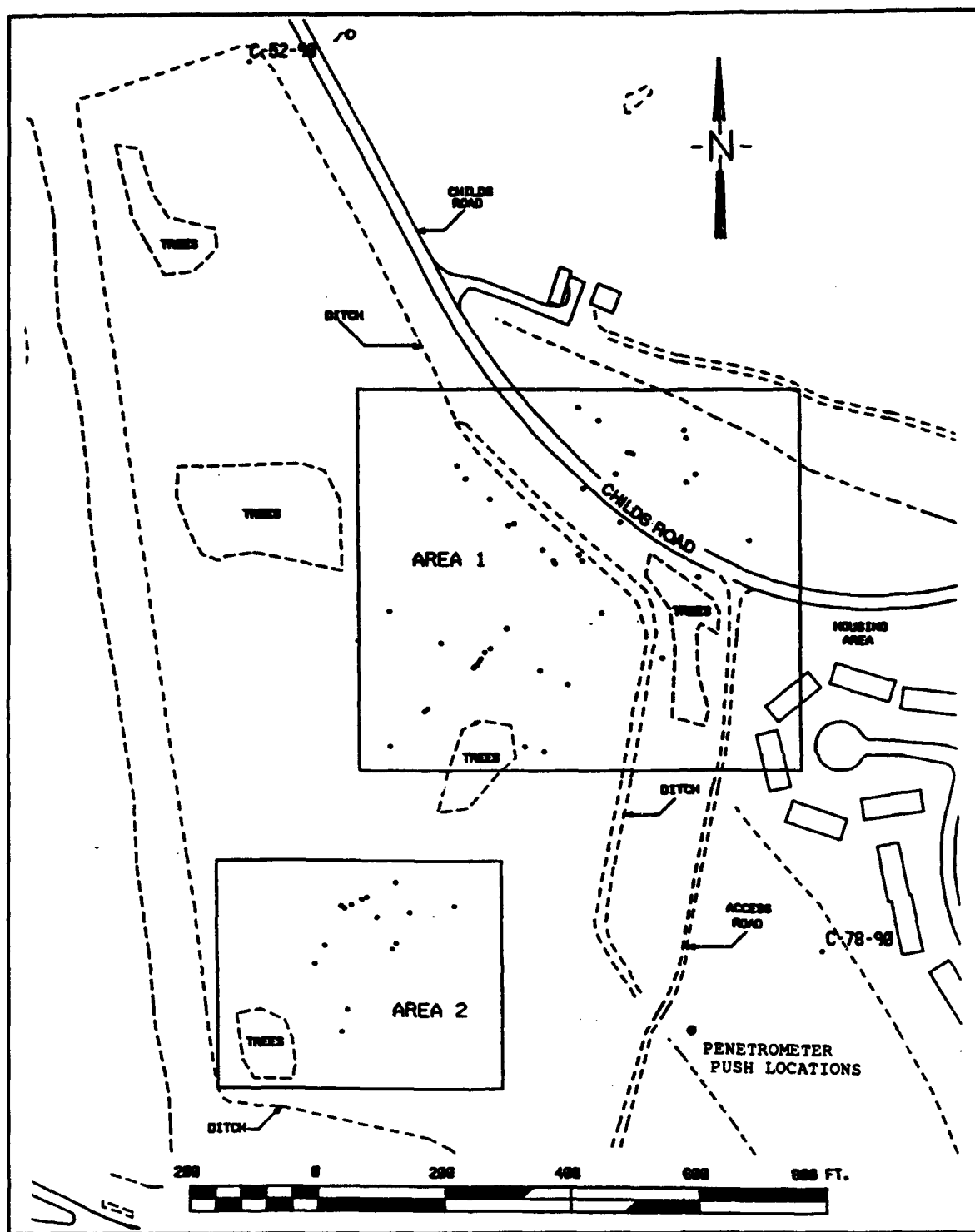


Figure 9. Location of penetrometer pushes in both test areas

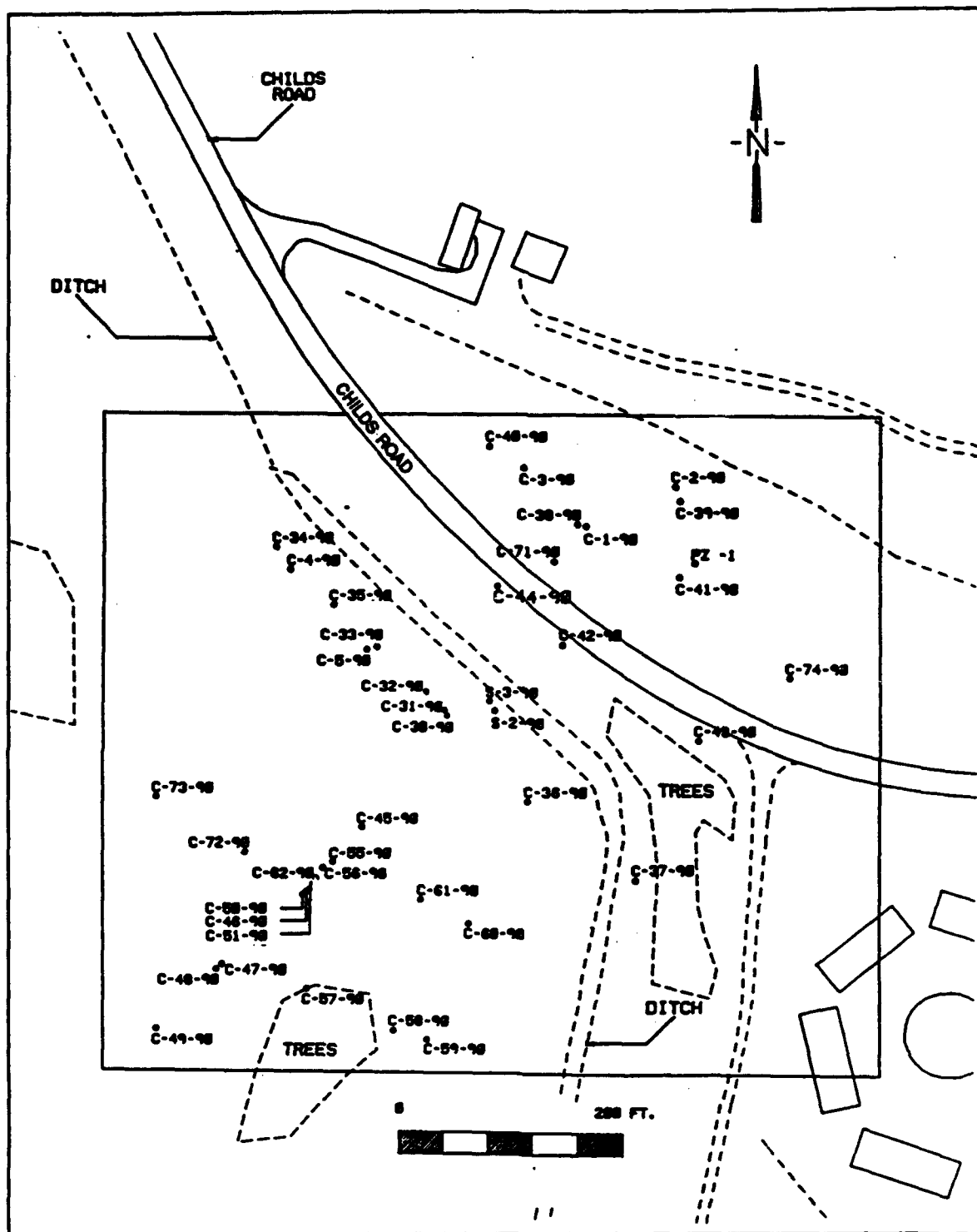


Figure 10. Location of penetrometer pushes in Test Area 1

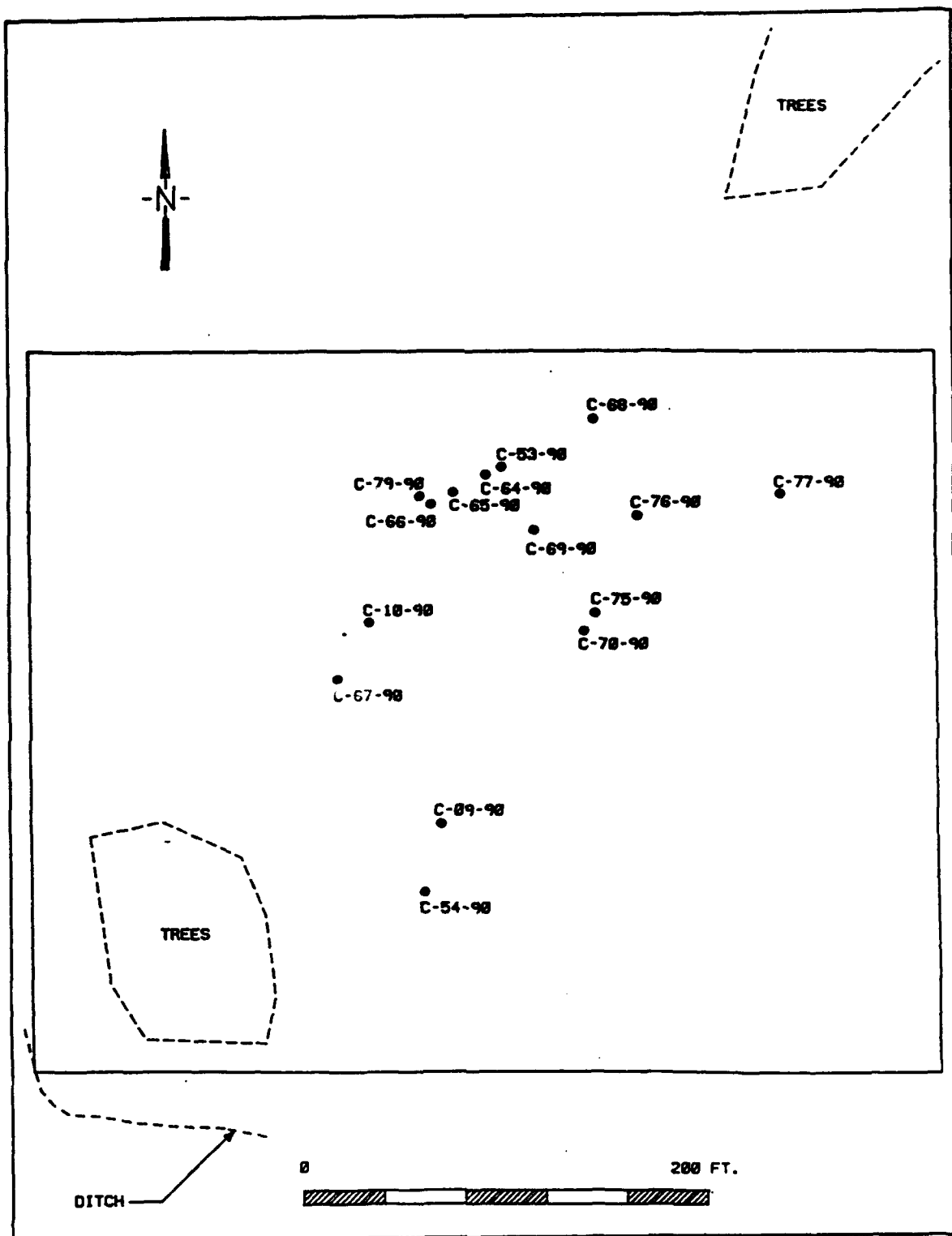


Figure 11. Location of penetrometer pushes in Test Area 2

the Jacksonville NAS. These solvents were not expected to have a significant (easily recognized) fluorescence anomaly that could be detected with the fiber optic tool. Most of the screening pushes in Area 2 were carried out using the resistivity tool. This tool could be expected to show dense chlorinated solvent contamination as a high resistivity anomaly in the soil media if there was sufficient chlorinated solvent to form a separated nonaqueous phase liquid.

The resistivity probe was calibrated by immersing the section carrying the electrodes in a tank of salt solution with known resistivity. The resistivity of the salt solution used in calibration was determined from temperature of the solution and the quantity of salt added and by comparing the measured resistivity (or conductivity) of the salt solution with a standard potassium chloride solution. A field portable conductivity cell was used to verify the resistivity of the salt solution used in the calibration. A detailed account of the procedure is given in Cooper et al. (1988).

## **Soil/Fluid Sampling**

Seven soil samples were collected. Two samples were taken from the sides and bottom of the ditch on the southwest side of Childs Road at a location immediately north of penetrometer hole C-30-90. These samples were obtained by digging obvious flow zone sediment out of the side and bottom of the ditch using hand shovels and trowels. The sample from the side of the ditch was at a depth of 2.4 m (8 ft) and the interval sampled extended approximately 0.46 (1.5 ft). The sample from the bottom of the trench was at a depth of 4.3 m (14 ft). The three other soil samples were collected using the Mostap Soil Sampler and were collected at various depths near penetrometer holes to provide partial confirmation of fluorometer measurements versus depth in penetrometer holes.

All of the soil samples were handled with clean equipment and placed in commercially prepared (precleaned) sample bottles (I-CHEM Research, Hayward, CA). All soil samples were packed in ice and shipped back to the Analytical Laboratory Group, Environmental Laboratory, WES, for analysis. The five samples from Test Area 1 (POL-contaminated area) were analyzed for oil and grease; the two samples from Area 2 (solvent-contaminated area) were extracted, and the extracts were run for volatile hydrocarbons.

A single water sample was collected near penetrometer hole C-76-90 that showed an anomalously high resistivity in soil media of typically low resistivity. This sample was treated with the same care as the soil samples and was submitted for analysis for volatile hydrocarbons.

## **Laboratory Testing of Samples**

Samples were received at the laboratory packed in ice and were maintained in refrigerated storage until the appropriate analyses were performed. The analytical laboratory at WES has full EPA certification. All samples were handled and analyzed using the approved EPA methodologies presented in "Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods," SW-846, September 1986, "Methods for the Chemical Analysis of Water and Wastes," EPA 600/4-79-020, March 1983, and "Procedures for Handling and Chemical Analysis of Sediment and Water Samples," EPA/CE-81-1, May 1981.

In this initial field testing, only eight water and soil samples were taken to evaluate the sampling methodology and sampler performance and to provide a limited verification of the penetrometer screening data by chemical analysis. An extensive sampling effort was not intended and could not have been executed because of time and funding constraints. In the process of collecting the samples both of the commercially available soil and water, samplers were broken. The loss of the equipment is due to encountering buried items at depths below the limits of investigation of the surface geophysical testing.

## 4 Summary of Results

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### Geophysical Survey

The results of the magnetic survey are given in Figure 12. The major magnetic anomalies were not in the survey area. The results are presented in parts per thousand deviation from the normal magnetic field. The magnetometer appeared to respond primarily to the local metallic debris scattered over the site. There was no pattern that could be related to the location of the disposal pits in either the northern or southern test areas.

The results of the soil conductivity survey are presented in Figure 13. The area shows a range of over 90 mhos/m in the northern penetrometer test area and a range of 60 mhos/m in the southern penetrometer test area. The local variations in resistivity in the northern test area were far larger than the variations observed over the extreme northern and southern parts of the surveyed area, suggesting local variation may be due to the trenches and the disposed materials buried in this area. Disposed oil should cause lower conductivity if the oil displaces local groundwater. The occurrence of lower conductivities near the northern end of the north area near Childs Road is consistent with the reported locations of the oil disposal pits. The southern test area was used primarily for disposal of degreaser and metal-plating waste, which would have produced less impact on the conductivity.

### Stratigraphic Assessment

Previous reports (Geraghty and Miller, Inc. 1980; Hart Associates, Inc. 1983) have presented stratigraphic sections through the area of the oil and solvent disposal site. The major features noted by previous investigators are as follows: (a) an upper layer that consists of 6 to 8 m (18 to 24 ft) of quartz sand with seams or layers of clayey sand; (b) a middle layer of clean quartz sand that is approximately 2 m (6 ft) thick; (c) a lower layer of quartz sand with interbedded clay that is approximately 1 to 2 m (3 to 6 ft) thick; and (d) a marine clay that is over 7 m (21 ft) thick. The upper three major stratigraphic units appear on the block diagram (Figure 14) prepared from the penetrometer data. The penetrometer, however, provides more detail, fine

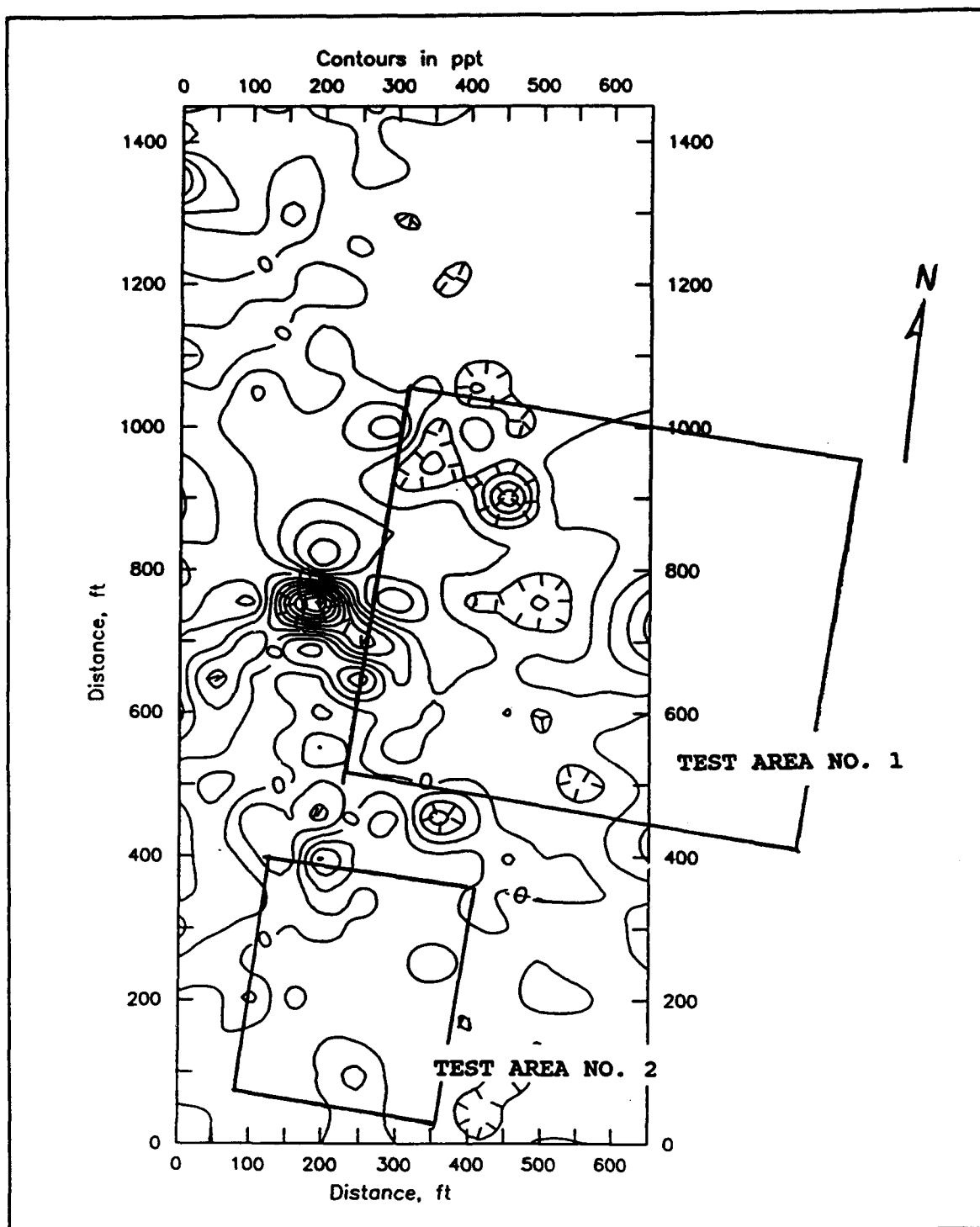


Figure 12. Magnetic survey of test areas

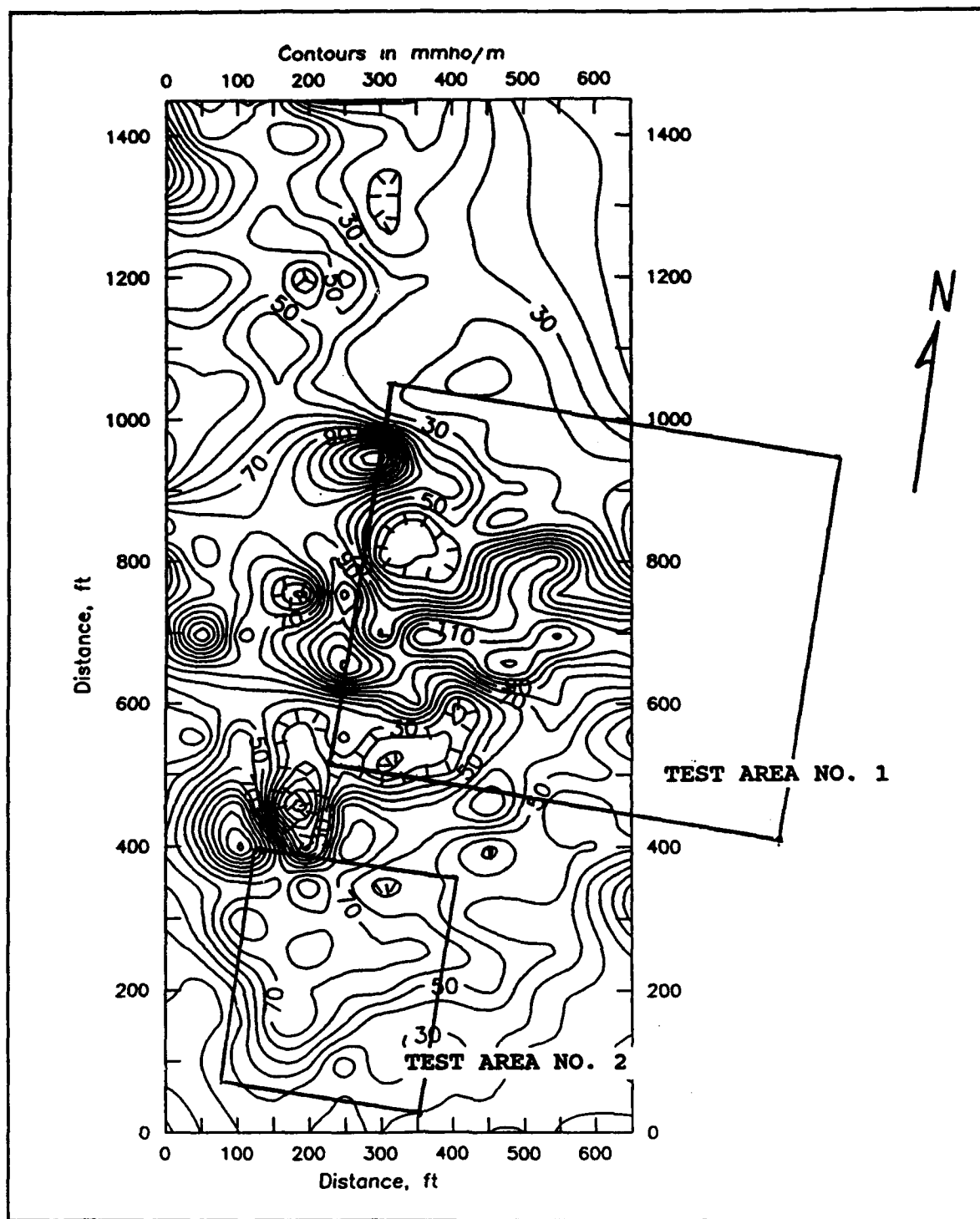


Figure 13. Induced electro-magnetic survey of test areas

resolution, and denser data points than any drilling log. The sand unit (b) shows a thin, continuous layer of near pure (soil classification 4) sand that extends across the diagram at an elevation of 2 to 4 m (6 to 12 ft) above sea level. Examination of the volume model with all penetrometer pushes (for the area included) shows that the sand, while nearly continuous through the block, does turn clayey toward the center of the study area. None of the sandy units shown in Figure 14 could be classed as continuous in three-dimensions.

The supposition from drilling logs that a continuous clean sand is present across Test Area 1 (Geraghty and Miller, Inc. 1980) at an elevation of 3 to 4 m above mean sea level is probably not valid.

The subsurface materials at the test area are best characterized as inter-bedded, lens-like units of clay, sandy clay, and sand. The penetrometer data indicate that monitoring the movement of contaminants in Area 1 with monitoring wells will be very difficult because of changes in soil characteristics and, therefore, permeability.

## **Field Testing for Petroleum Contamination**

Petroleum contamination was mapped using the fiber optic fluorometric sensor. Thirty-six probe pushes were made with the fluorometric sensor with a maximum depth of 7 m (23 ft). The results are presented in Appendix A. Thirty-four fluorometer pushes in Area 1, the closed oil disposal area, were used to map the occurrence of contaminated soil in detail. The distribution of oil-contaminated soil down to fluorescence levels that are equivalent to the fluorescence of soil contaminated with 1,000 ppm of fresh marine diesel fuel is presented in Figures 15-26. The pattern of oil distribution shown in Figure 27 (from Geraghty and Miller, Inc. 1980) demonstrates that the same area determined by other investigators to be involved in the oil contamination was accurately located in this investigation using the fluorometric sensor. The fringes of the contaminated soil are shown with more detail in the penetrometer-based report because of the greater control and the close placement of sensor holes. As the interactive volume model produces diagrams of higher concentration levels, it is possible to see the source areas for the petroleum contamination that should be the locations of the old disposal pits. This type of map can be far more useful in planning further remedial activity than a simple contour map developed from analysis of well samples from arbitrarily placed monitoring wells that sparsely populate an area of interest.

## **Field Testing for Solvent Contamination**

The DC resistivity probe was primarily used in Area 2 to look for resistivity changes that would be related to solvent or paint waste disposal. Ten pushes with the resistivity probe were made in Area 2. The data are presented in Appendix B. Generally, no response that could be related to the occurrence

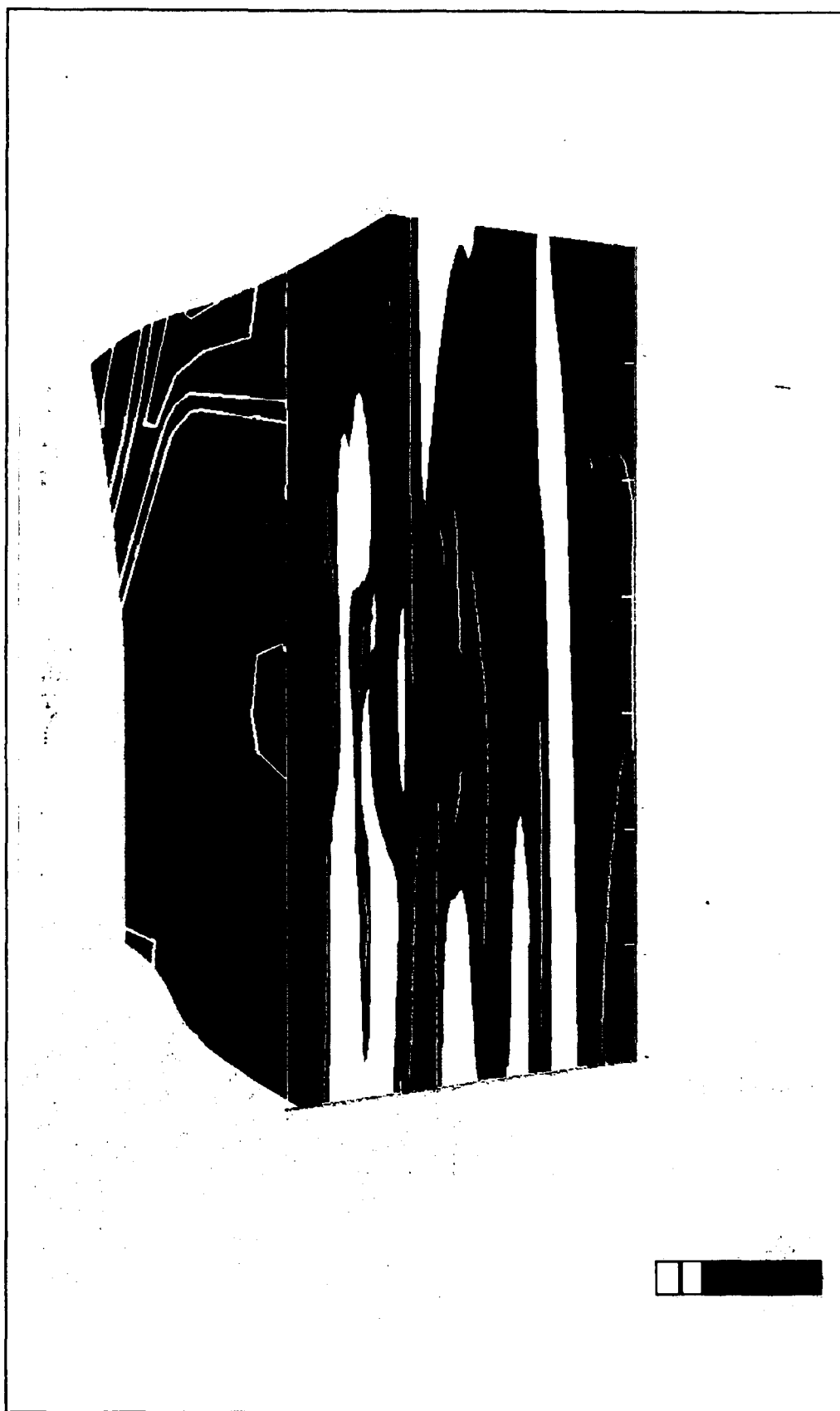


Figure 14. Stratigraphic section for the disposal site. The block diagram shows Test Site 1 with the soil type shown as determined from the penetrometer. A pure sand is Soil Class No. 5 (white) and a pure clay is Soil Class No. 1 (blue). Mixtures are designated by intermediate numbers in the series



Figure 15. Soil volume contaminated at over 1,000 ppm DFM equivalent (view looking north)



Figure 16. Soil volume contaminated at over 1,000 ppm DFM equivalent (view looking east)

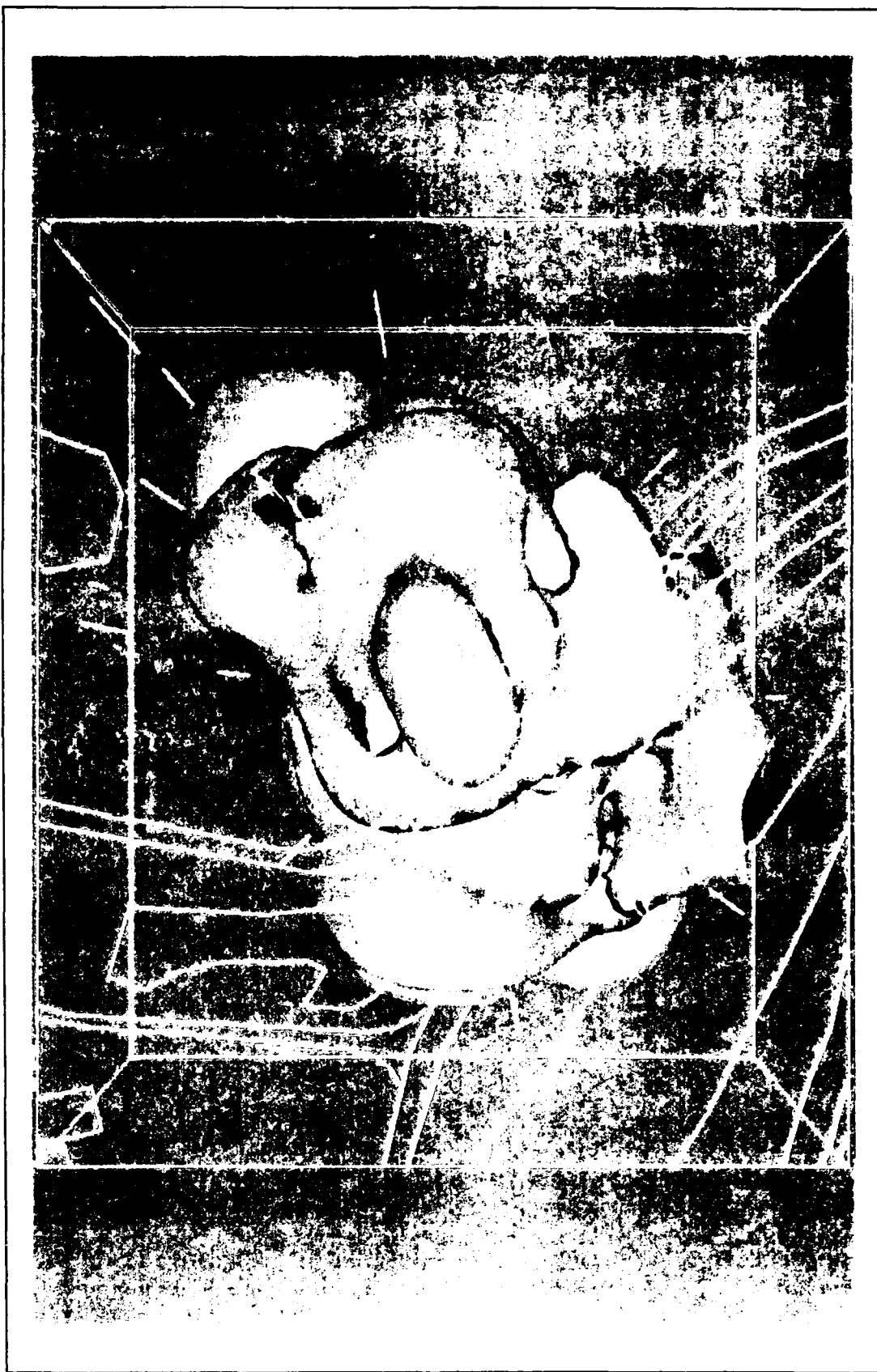


Figure 17. Soil volume contaminated at over 1,000 ppm DFM equivalent (view looking down)

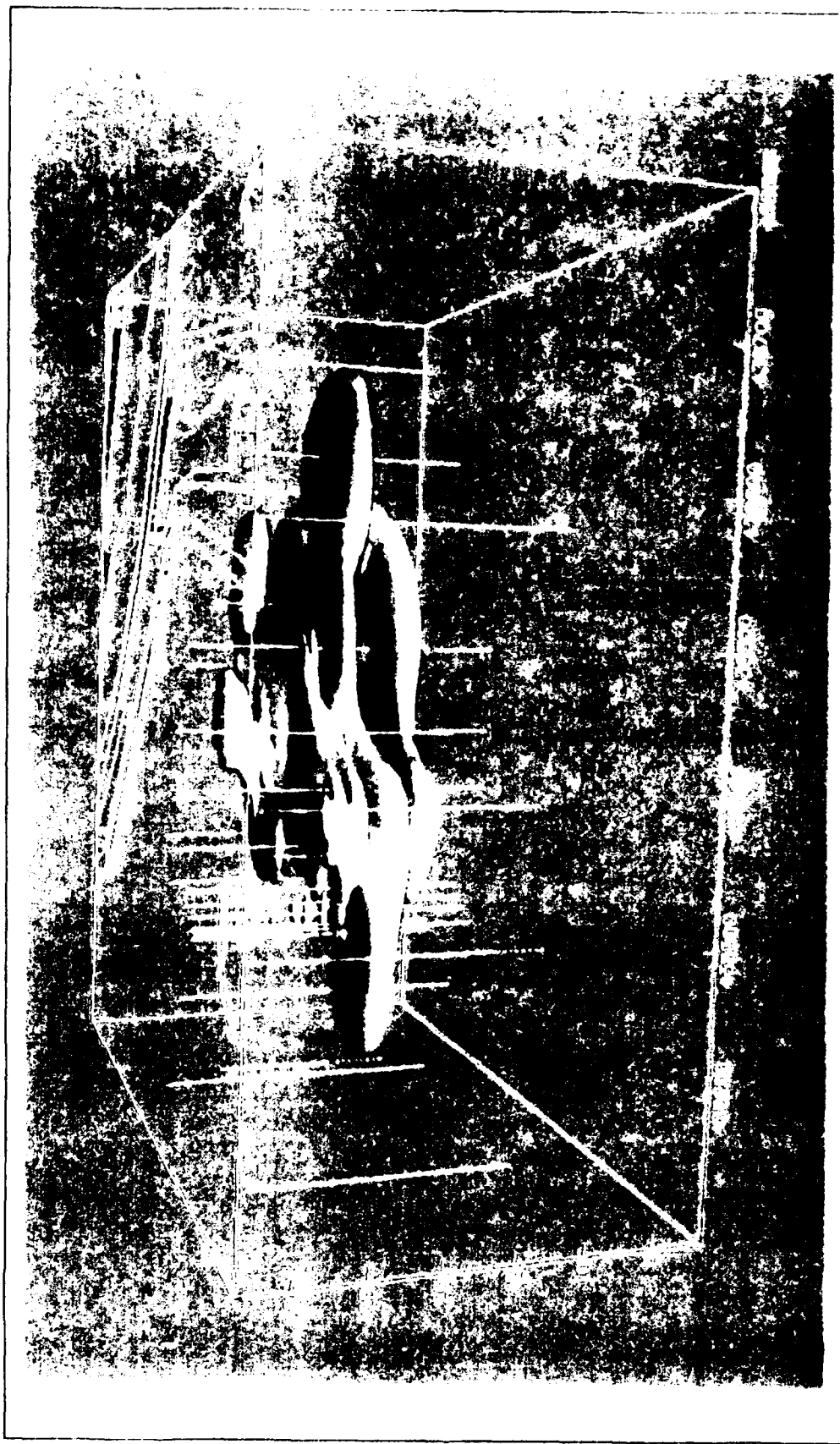


Figure 18. Soil volume contaminated at over 4,000 ppm DFM equivalent (view looking north)

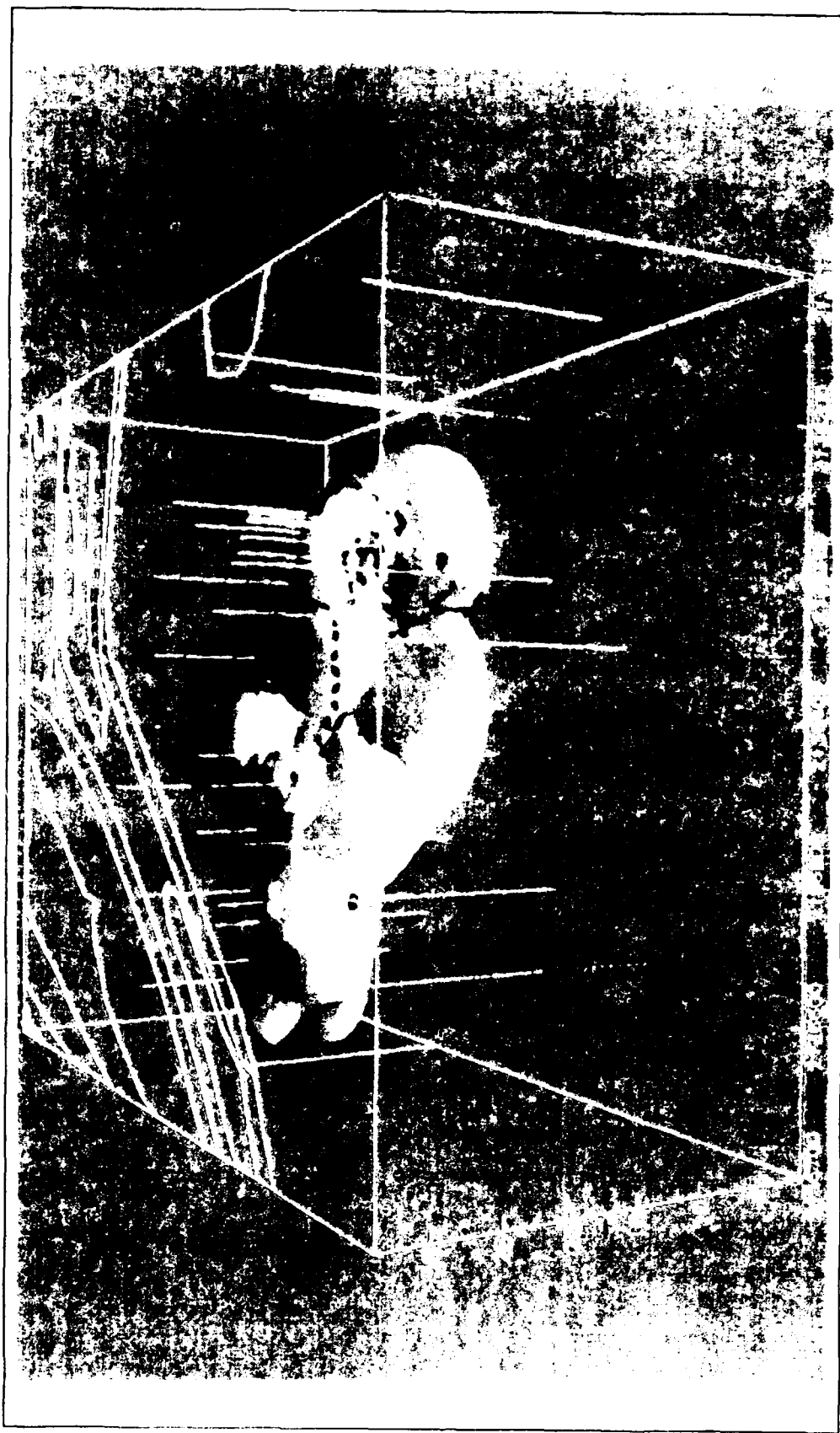


Figure 19. Soil volume contaminated at over 4,000 ppm DFM equivalent (view looking east)



Figure 20. Soil volume contaminated at over 4,000 ppm DFM equivalent (view looking down)

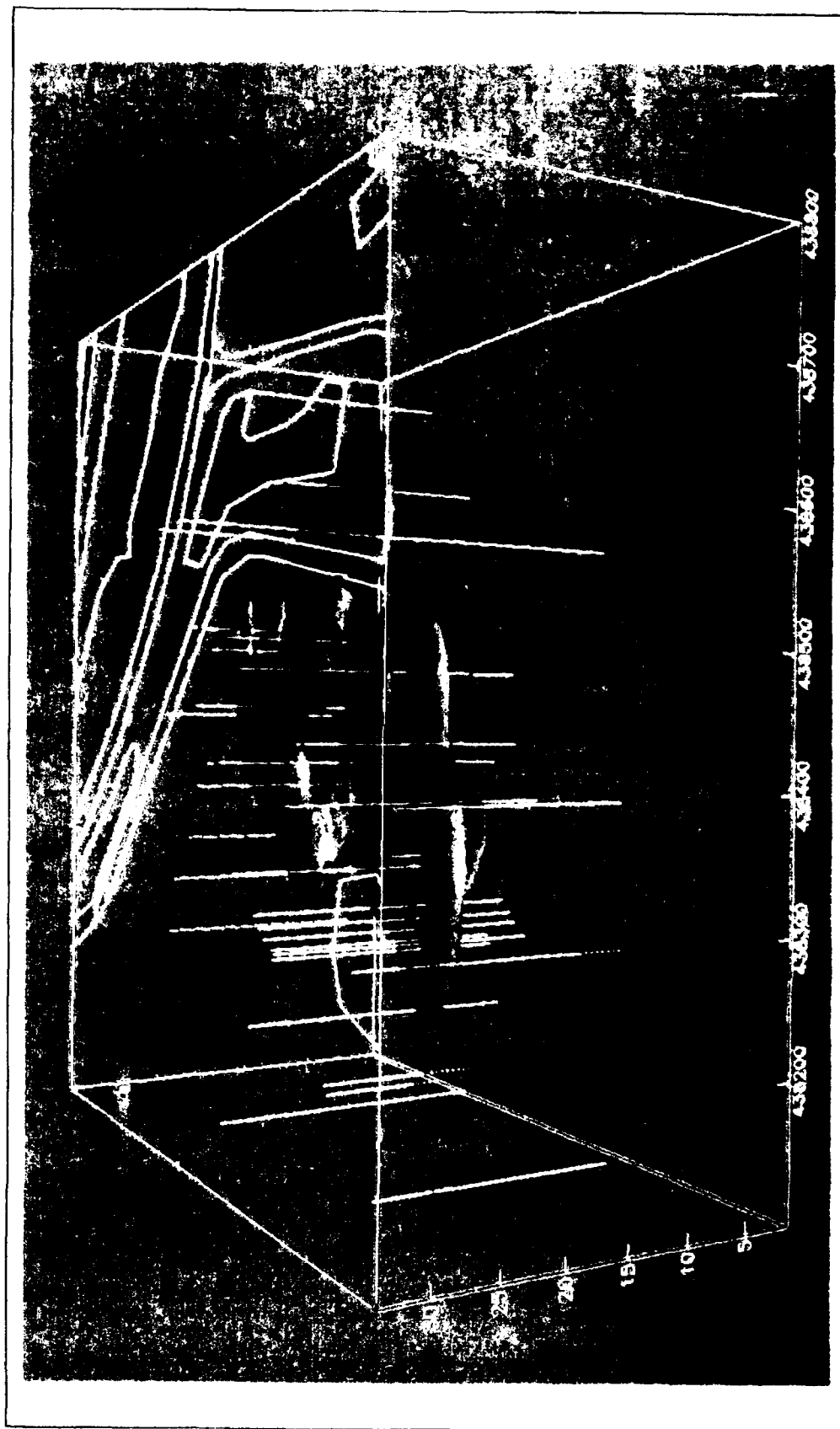


Figure 21. Soil volume contaminated at over 8,000 ppm DFM equivalent (view looking north)

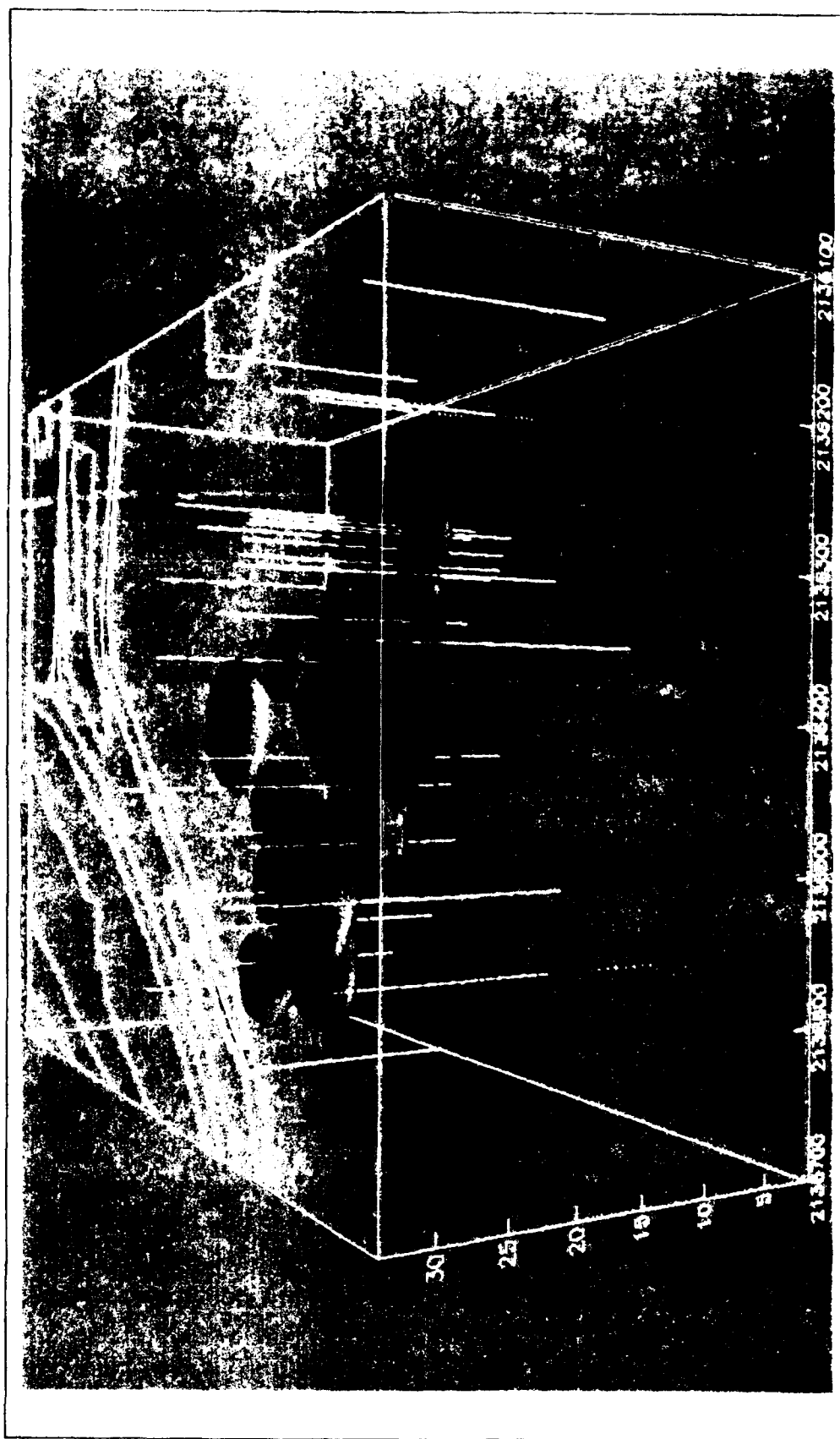


Figure 22. Soil volume contaminated at over 8,000 ppm DFM equivalent (view looking east)

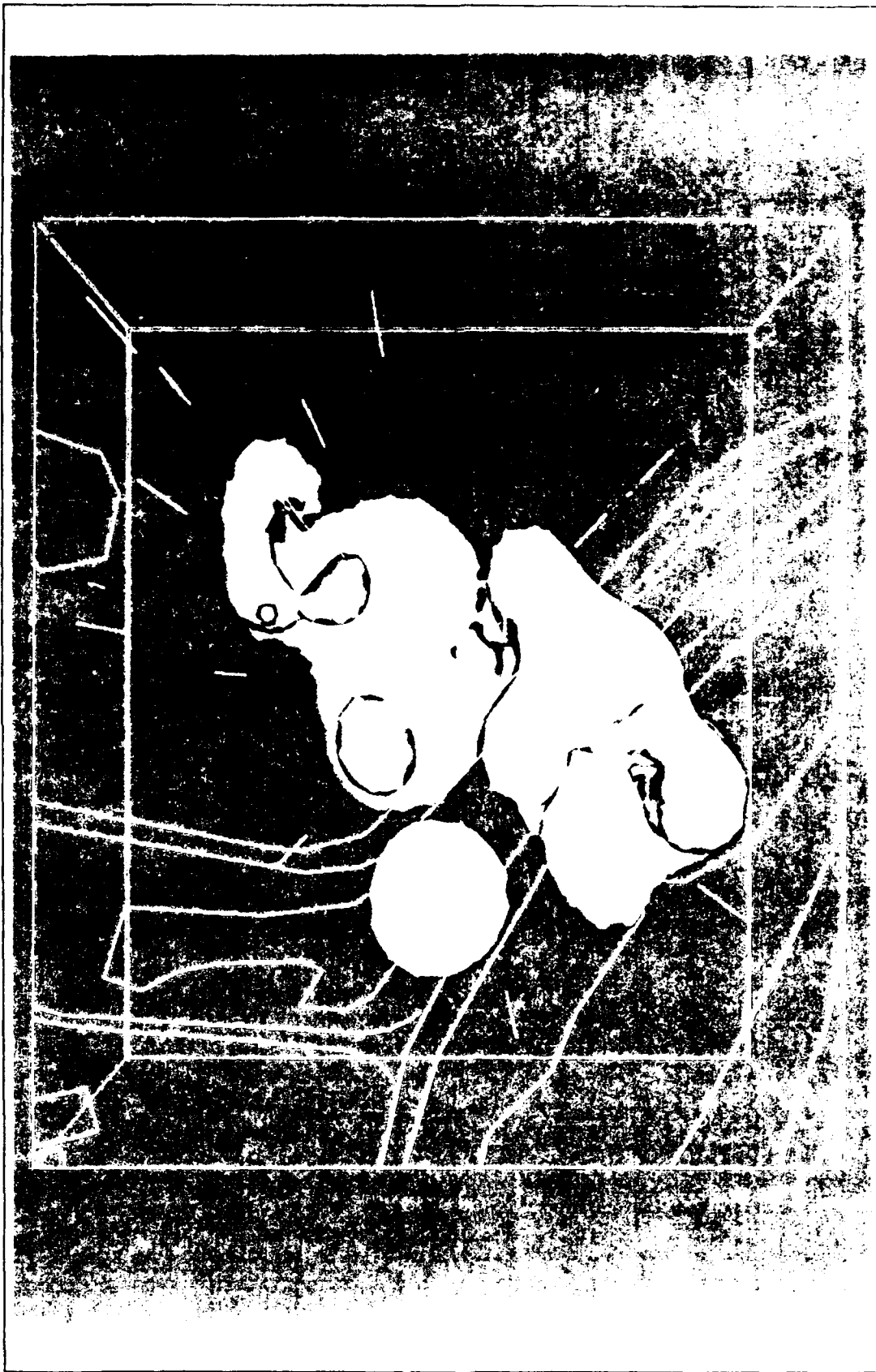


Figure 23. Soil volume contaminated at over 8,000 ppm DFM equivalent (view looking down)

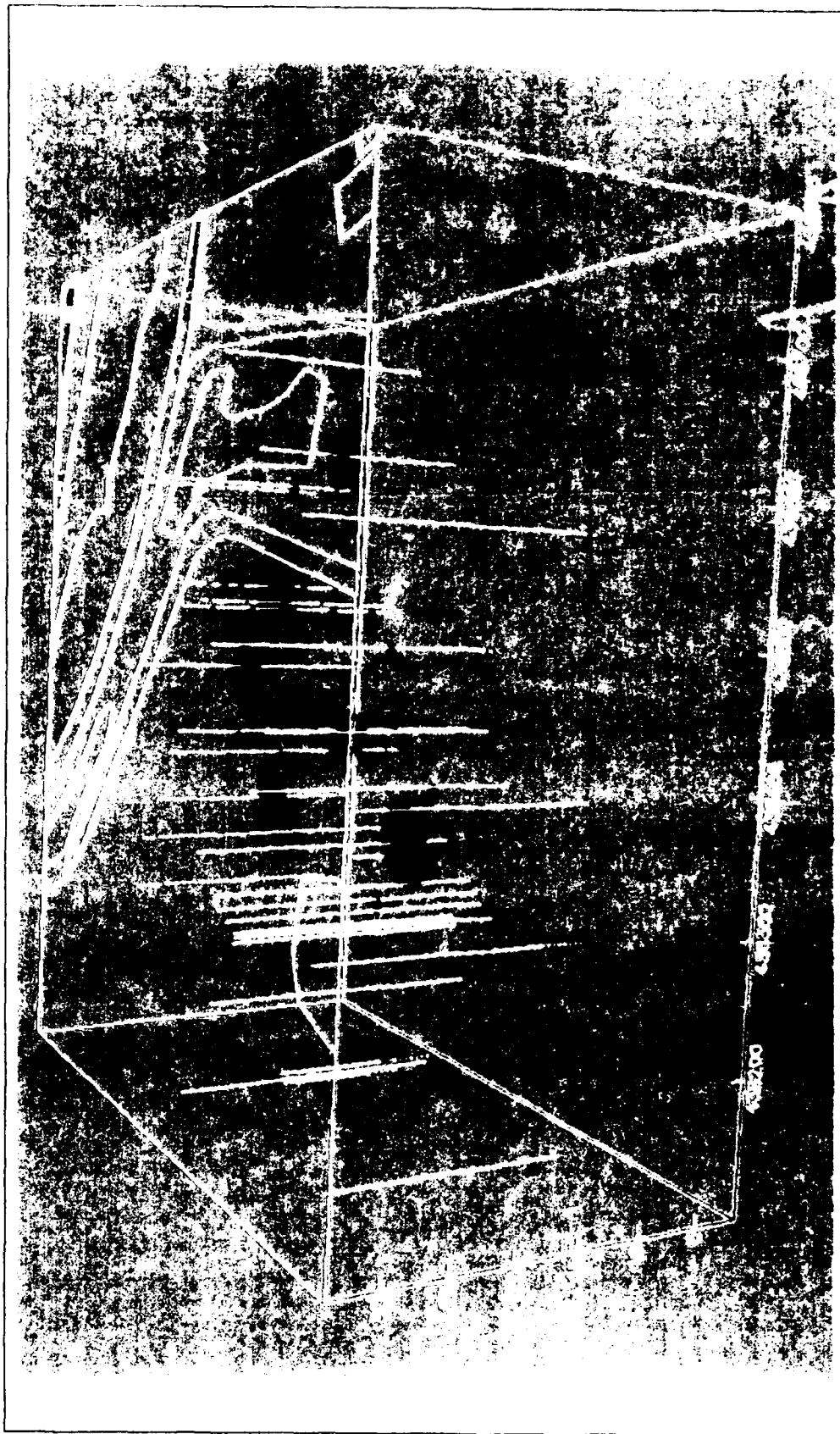


Figure 24. Soil volume contaminated at over 16,000 ppm DFM equivalent (view looking north)

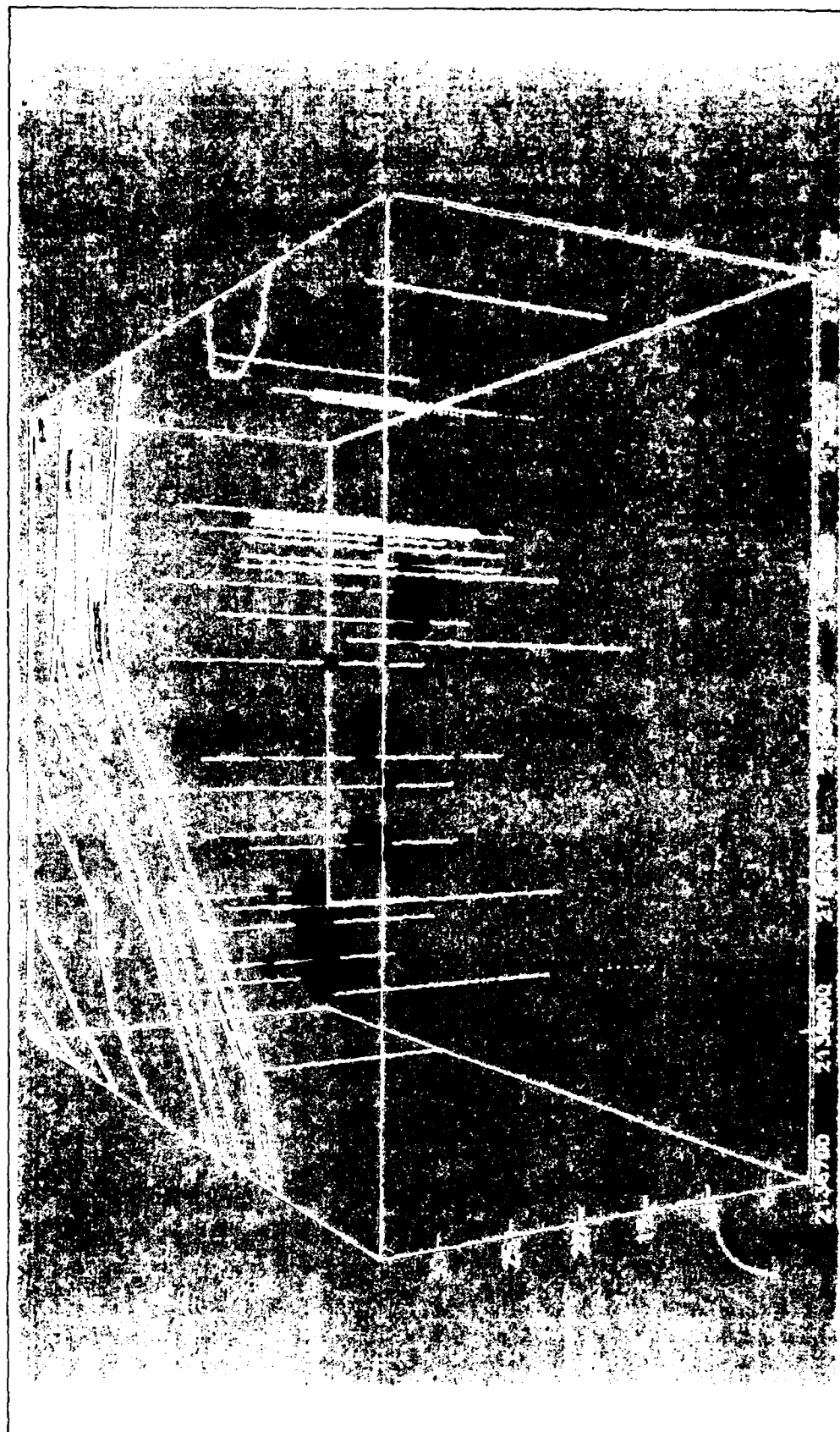


Figure 25. Soil volume contaminated at over 16,000 ppm DFM equivalent (view looking east)

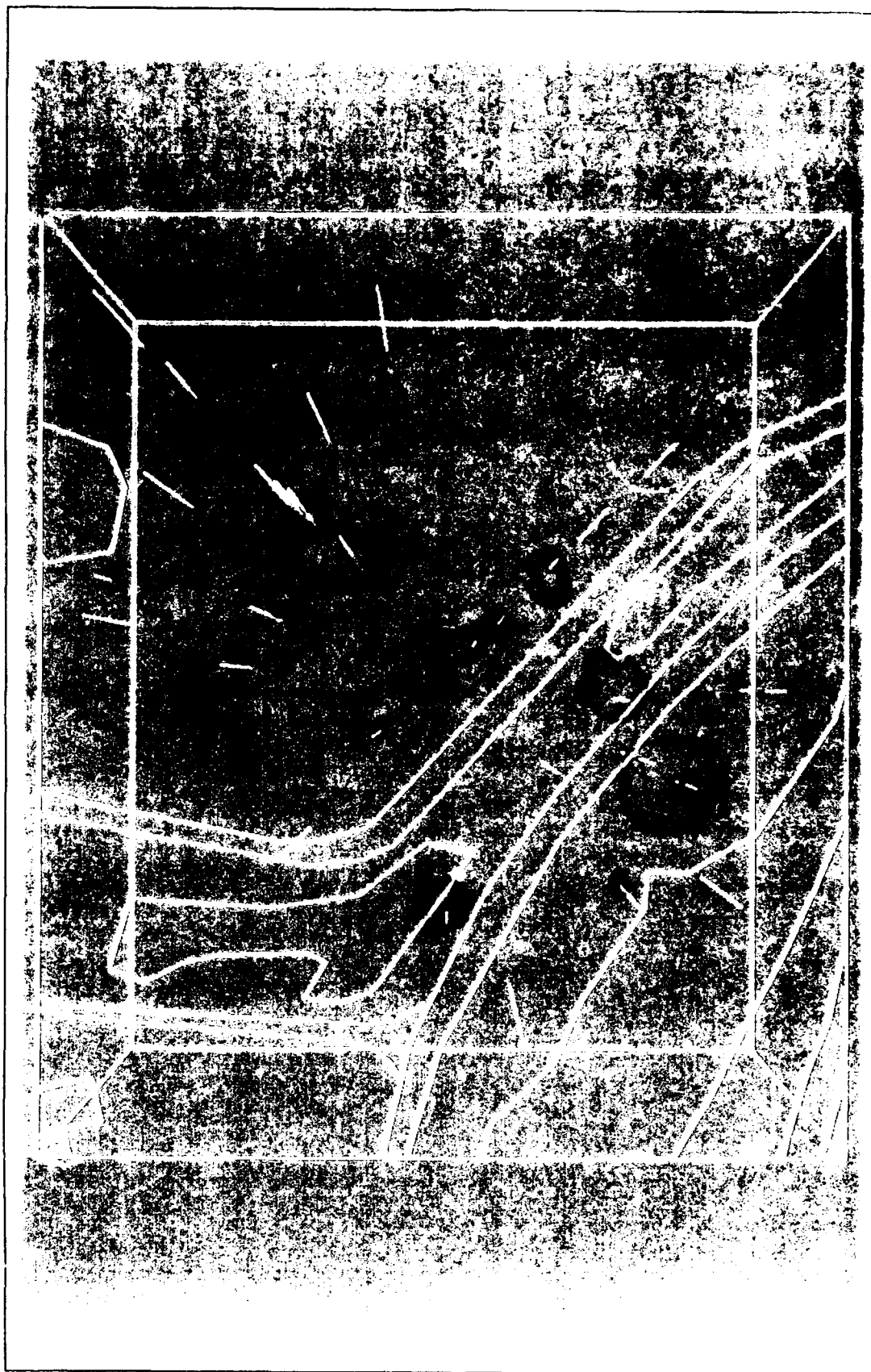


Figure 26. Soil volume contaminated at over 16,000 ppm DFM equivalent (view looking down)

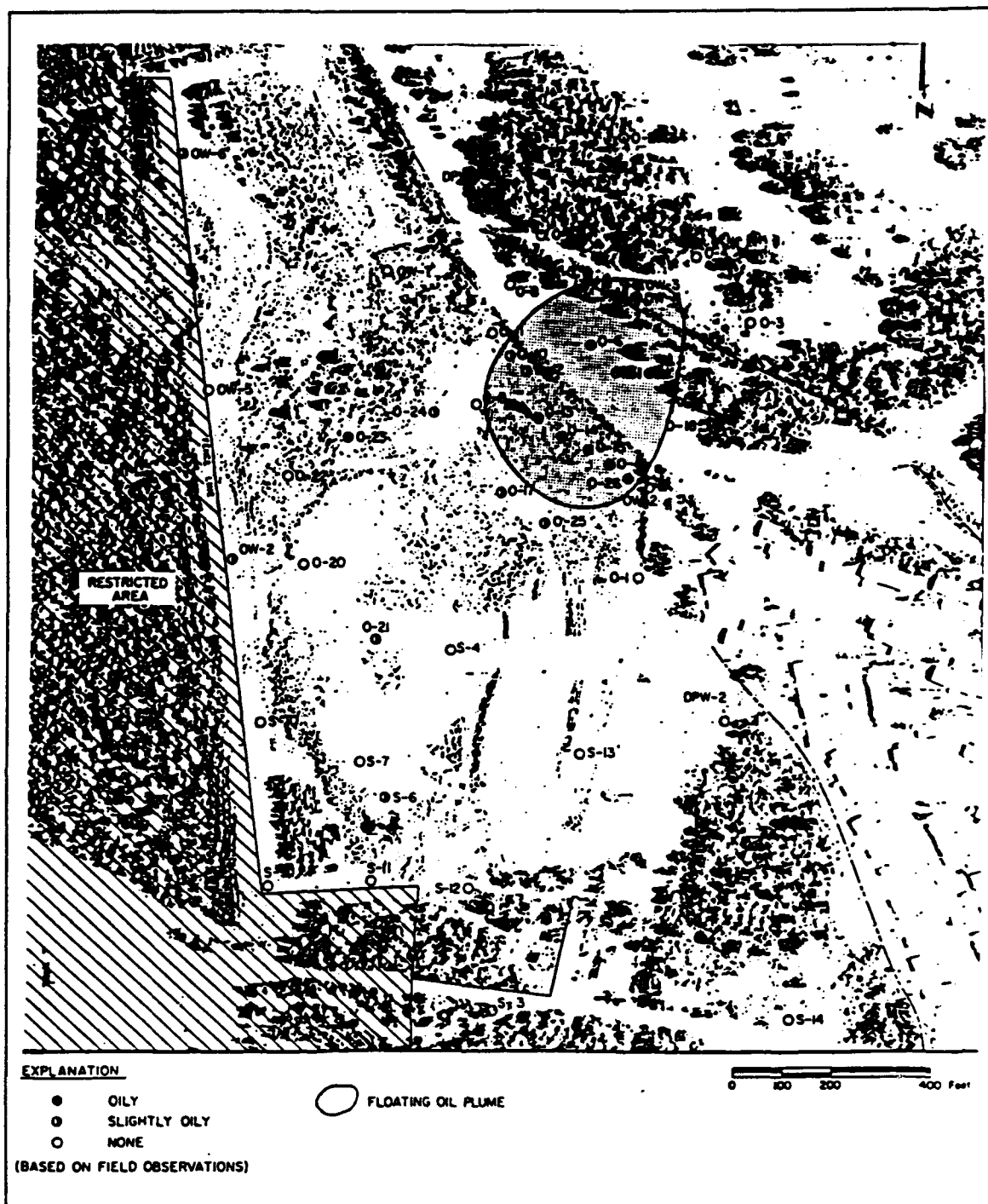


Figure 27. Plume of oil contamination mapped with drilling and sampling from Geraghty and Miller, Inc. (1980)

of solvent or the disposal of metal-rich paint wastes could be found. The major anomaly that was observed below the water table related to high resistivities that occurred at depths below 13 m (42.6 ft) in holes pushed at C-76-90 and C-77-90. A water sample was obtained near these holes, and the results of the analysis for solvents are presented in Appendix C.

## Sampling and Sample Analysis

Both water and soil samples were taken with the penetrometer unit. The results obtained from the analysis of the samples are presented in Appendix C. The Hydropunch water sampler was used to collect a water sample in Area 2, but was damaged in a second attempt to collect water in the same area. The water sample collected near C-76-90 showed no detectable contamination.

Five soil samples were collected with the Mostap sampler from Areas 1 and 2. The three samples from Area 1 showed varying levels of hydrocarbon (oil and grease) contamination from 175 ppm to 62,500 ppm. The variation in the concentration of the hydrocarbons in the soil samples were consistent with the variation that has been observed in the record from the fluorometric sensor.

Two soil samples were collected in Area 2. Only the shallow sample from C-77-90 showed any appreciable solvent contamination. Analysis for solvents showed the presence of methylene chloride and 1,1,2,2-tetrachloroethane, along with toluene, P-xylene, chlorobenzene, and ethylbenzene. The deep sample (from 45 ft below C-66-90) showed only a minor amount of methylene chloride. The shallow soil sample demonstrated that there was definite solvent contamination. The electrical resistivity could not be reliably correlated with the concentration of solvent at this depth because of "edge effects" on the resistivity probe at this shallow depth above the water table. The second soil sample was taken at a depth that showed an unusual increase in resistivity. The analytical results indicate that the resistivity change is due to a decrease in the resistivity of the groundwater, not to an accumulation of organic solvents.

Comparison of Fluorescence and Laboratory Test Results from Soil Samples					
Sample No.	Nearest Cone Penetrometer Test	Sample Depth ft	Count Ratio	Prediction Based on DFM (ppm) Calibration	Analytical Sample Test Results O & G ppm
07048	C-30-90	11.0	0.012	240	175
07044	C-30-90	9.0	0.200	25,934	22,570
07045	C-30-90	13.5	0.500	60,000	56,600
07046	C-62-90	9.5	0.160	20,582	62,500

Samples 07048, 07044, and 07045 were dug from the wall of a drainage ditch approximately 20 ft from penetrometer push C-30-90. These samples were measured with the fluorometer tool at the surface. Sample 07046 was obtained with a MOSTAP soil sampler approximately 5 ft away from penetrometer push C-62-90; however, the compared fluorescence measurement was made in situ during the push. The variability in contaminant concentration in soil may account for the difference in predicted versus sample test results for this case.

## 5 Conclusions

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The field test at the Jacksonville NAS provided a wide range of information with regard to the application of the SCAPS unit. Major conclusions developed from this exercise include the following:

- a.* The penetrometer can be successfully used with multiple sensors such as the fluorometric sensors and the tip and sleeve soil strength measuring devices.
- b.* The fluorometric sensors can be successfully employed to produce a detailed delineation of a hydrocarbon (POL) plume that far exceeded the capability of the usual drill-and-sample site investigation.
- c.* Neither the fluorometric sensor nor the resistivity sensor in their present configuration could detect chlorinated hydrocarbons in the levels present at the Jacksonville NAS ( <5 ppm total chlorinated hydrocarbon).
- d.* The commercial soil and groundwater samplers successfully functioned in collecting samples, but were not hardened sufficiently to survive in soil with buried obstacles such as found at the Jacksonville NAS.
- e.* The analyses obtained from soil and water samples were consistent with the estimates of contamination obtained with the sensors.
- f.* A water sample taken at a depth below 13 m showed no evidence of solvent contamination, indicating that the increased resistivity is due to the presence of clean water with a low conductivity.
- g.* The interactive volume model is a useful technique for rapidly reducing the large volume of data developed from a sensor-equipped penetrometer survey of a hazardous waste site.

## 6 Recommendations

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The experience with the SCAPS unit at the Jacksonville NAS allows the following recommendations to be made:

- a.* The double fiber fluorometric sensor should be developed as the standard POL sensor. The system has low maintenance and collects data satisfactorily.
- b.* The resistivity sensor should be specifically used when contrast in electrical properties is a major feature in the contaminated subsurface materials.
- c.* The soil strength measurements should be continued as an integral part of the sensor systems.
- d.* The samplers used with the penetrometer must be designed to withstand impact with obstacles in the subsurface.
- e.* Future field efforts should include a side-by-side comparison of sensor output and sample analyses so that the response of the sensors can be carefully assessed under a variety of circumstances. Questions regarding possible adverse effects from soil matrices and interference from naturally occurring fluorescent compounds in soil or multiple contaminants of uncertain origin should be a high priority effort.
- f.* A viable in situ grouting system should be developed that does not introduce hazardous substances, is inert, and can be used during probe retraction.

# References

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- Cooper, S. S. et al. (1988). "Development of a computerized penetrometer system for hazardous waste site soils investigations," Report No. AMXTH-TR-TE-882452, U. S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, MD.
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- Lieberman, S. H., Inman, S. M., and Theriault, G. A. (1989). "Use of time-resolved spectral fluorometry for improving specificity of fiber optic-based chemical sensors." *Proceedings SPIE optoelectronic and fiber optic devices and applications*.
- Olsen, R. S. (1988). "Using the CPT for dynamic site response characterization." *Proceedings of the Earthquake Engineering and Soil Dynamic II Conference, American Society of Civil Engineers, Park City, UT, June 27, 1988*.

Olsen, R. S., and Farr, J. V. (1986). "Site characterization using the Cone Penetrometer Test," Proceedings of the Specialty Conference entitled *Use of In Situ Tests for Geotechnical Engineering*, American Society of Civil Engineers, Blacksburg, VA.

# Appendix A

## Data from the Penetrometer Unit Equipped with a Soil Strength Measuring System and the Fluorometric Sensor

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### Explanation of Plot Formats

The figures presenting plots of penetrometer data versus depth are organized in panels. Data obtained with the Site Characterization and Analysis Penetrometer System (SCAPS) resistivity tool are shown in four panels, i.e., point penetration resistance  $q_p$  in tons/square feet versus depth in the first (left hand) panel, sleeve friction  $f_s$  in tons/square feet versus depth in the second panel, soil classification computed from  $q_p$  and  $f_s$  versus depth in the third panel, and soil resistivity in ohm-feet versus depth in the fourth panel.

Data obtained with the SCAPS fiber-optic fluorescence tool are shown in seven panels. The first three panels show  $q_p$ ,  $f_s$ , and soil classification versus depth as described previously. The fourth panel shows raw fluorescence intensity versus depth; the fifth panel shows predicted equivalent concentration of diesel fuel in parts per million (ppm) versus depth; the sixth panel shows a log-log plot of predicted equivalent concentration of diesel fuel in ppm versus depth; and the seventh panel shows a plot of the wavelength at which the peak fluorescence intensity occurred versus depth.

The first three panels in each figure deal with point penetration resistance  $q_p$ , friction sleeve resistance  $f_s$ , and the soil classifications derived from them. In the most general sense, cohesive soils (clays) tend to adhere (stick) to the friction sleeve, whereas, noncohesive soils (sands) do not. Hence, the  $f_s/q_p$  is typically higher in clays than in sands, and soil admixtures (silty sand, sandy clay, etc.) exhibit intermediate  $f_s/q_p$  ratios. This is the (simplistic) basis for calculating soil classification from  $q_p$  and  $f_s$  measurements made with an electric instrumented cone. For additional information on cone penetrometer

strength data and interpretations, the reader is referred to the literature (Olsen 1988).<sup>1</sup>

Soil resistivity measurements are routinely made in surface geophysical surveys, in borehole logging, and less frequently used penetrometers. Resistivity measurements are used typically in conjunction with other measurements to identify soil layering or to sense the presence of moderate to high concentrations of contaminants in these layers. However, when contaminant concentrations are low (a few tens of a part per million) soil resistivity changes will generally be too subtle to detect. Under best case conditions, there will be a significant contrast in resistivity measured in a contaminated zone versus measurements made in an uncontaminated host soil. High concentrations of petroleum, oil, and lubricants (POL) in the predominately sandy soil at Jacksonville Naval Air Station (NAS) should consistently be detected as high resistivity anomalies since hydrocarbons are usually excellent insulators. However, local variations in soil composition and groundwater can also produce appreciable changes in resistivity measured in the same soil layer. Hence, in situ soil resistivity measurements are inherently ambiguous and nonspecific regarding contaminant type; apparent resistivity anomalies should be evaluated by other means, preferably by physical sampling.

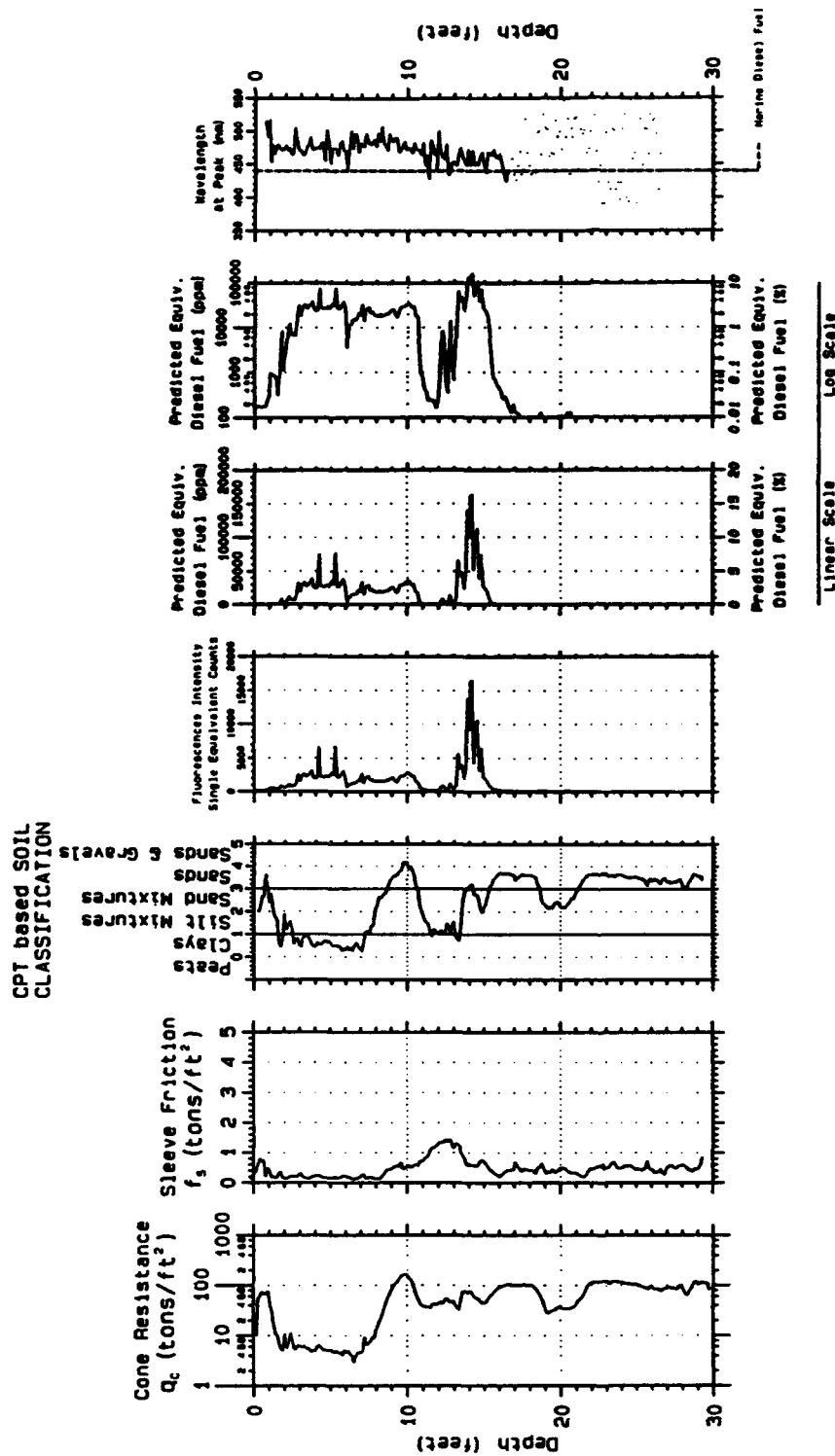
As previously discussed, the figures presenting the fluorometric measurements made with the SCAPS fiber-optic tool are arranged in seven panels. The first three panels show soil strength ( $q_c$  and  $f_s$ ) and soil classification versus depth measurements that are common to both the resistivity and fiber-optic tools. The remaining panels of fluorometric data were designed to facilitate comparisons of results at different penetration locations and as an expedient way to summarize a very extensive database. The fourth panel shows a linearly scaled plot of raw fluorescence intensity data versus depth. This panel permits a rapid comparison of the magnitude of fluorescence anomalies encountered across the site. The fifth panel presents a linearly scaled plot of predicted equivalent diesel fuel concentration in ppm versus depth. Comparison of panels four and five should indicate that the general data trend is preserved when the diesel equivalency calculation is made. Panel six presents a log-log plot of predicted equivalent diesel fuel concentration in ppm versus depth. This panel was included to facilitate comparisons of relatively low level predicted POL concentrations. The final panel, panel seven, shows a plot of wavelength at peak fluorescence intensity versus depth.

The wavelength plot provides a means to judge the source of the fluorescence being detected. For example, when the tool is being advanced through clean soil, no fluorescence is detected; the wavelength peak intensity algorithm is reading random system noise (approximately 10 to 20 counts). Consequently, the wavelength determination is inconsistent. However, when a significant fluorescence signal (50 counts) is detected, the wavelength plot can be a useful indicator of the kind of fluorescence source being measured. In the

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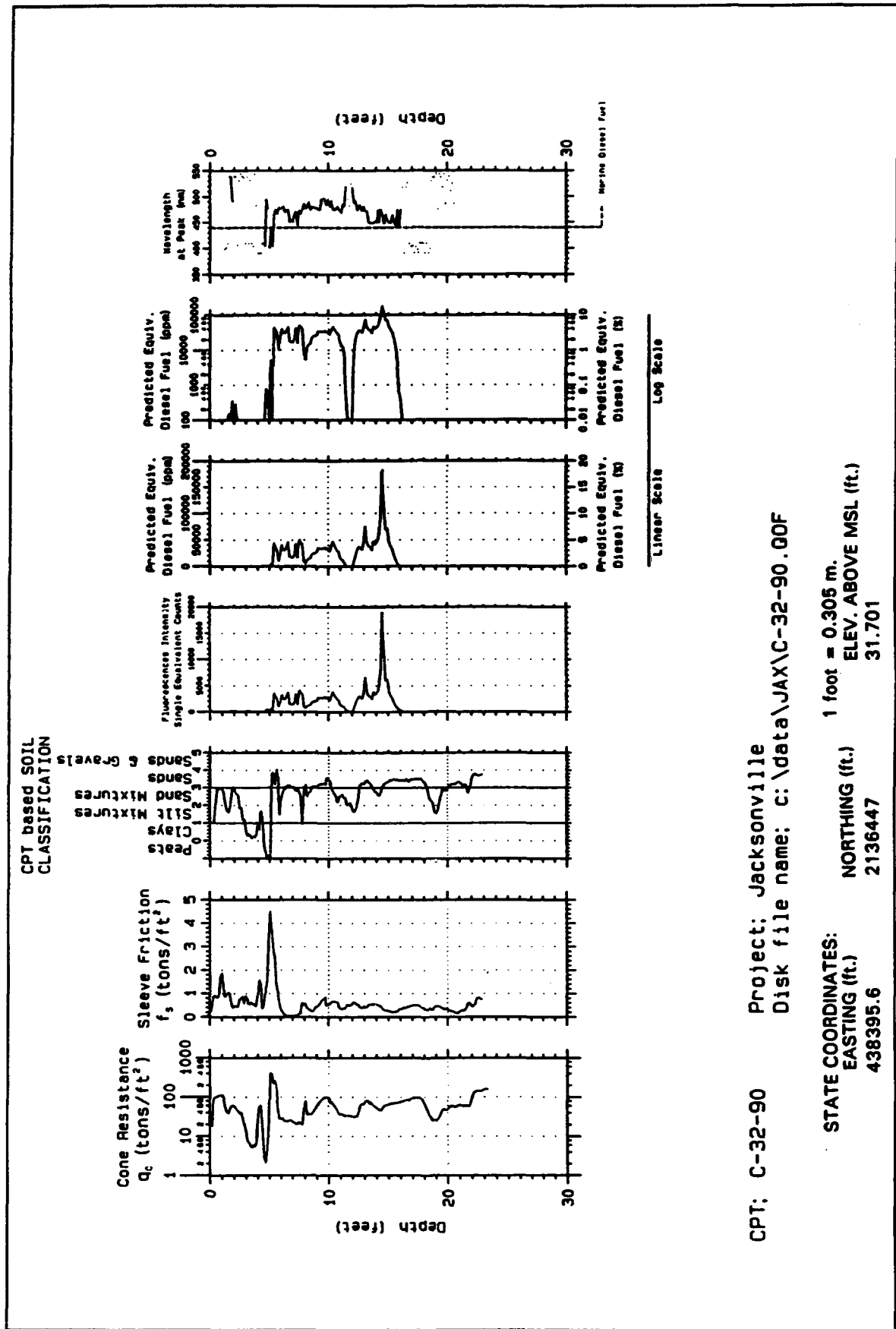
<sup>1</sup> References cited in this appendix are located at the end of the main text.

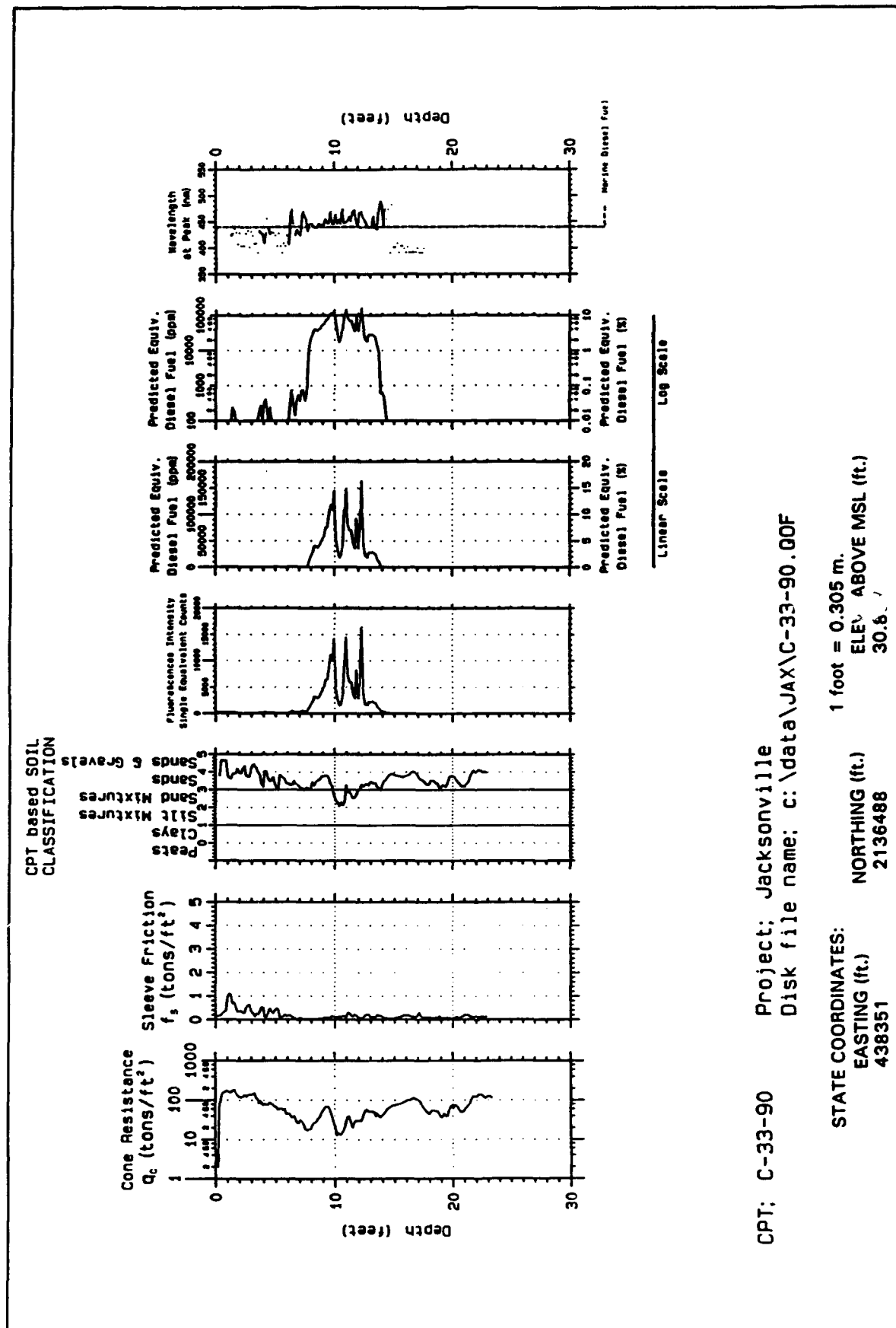
case of Jacksonville POL contamination, physical samples obtained near surface and from seep zones 10 ft down in the intercept trench were tested with the fluorescence tool and showed peak wavelengths in the range from 430 to 460 nm. Hence, POL anomalies detected in situ at Jacksonville NAS with the fluorescence tool should presumably show comparable wavelengths. At this writing, it is known from extensive bench testing that freshly refined petroleum products can usually be differentiated according to their spectral (wavelength) fluorescence. But, little is known about the same products after 20 to 30 years residence in soil. This is the first time that in situ fluorescence measurements have been successfully made with penetrometer equipment, and only with additional testing to enlarge the fluorescence database will more informed judgements be possible at mixed POL waste sites.

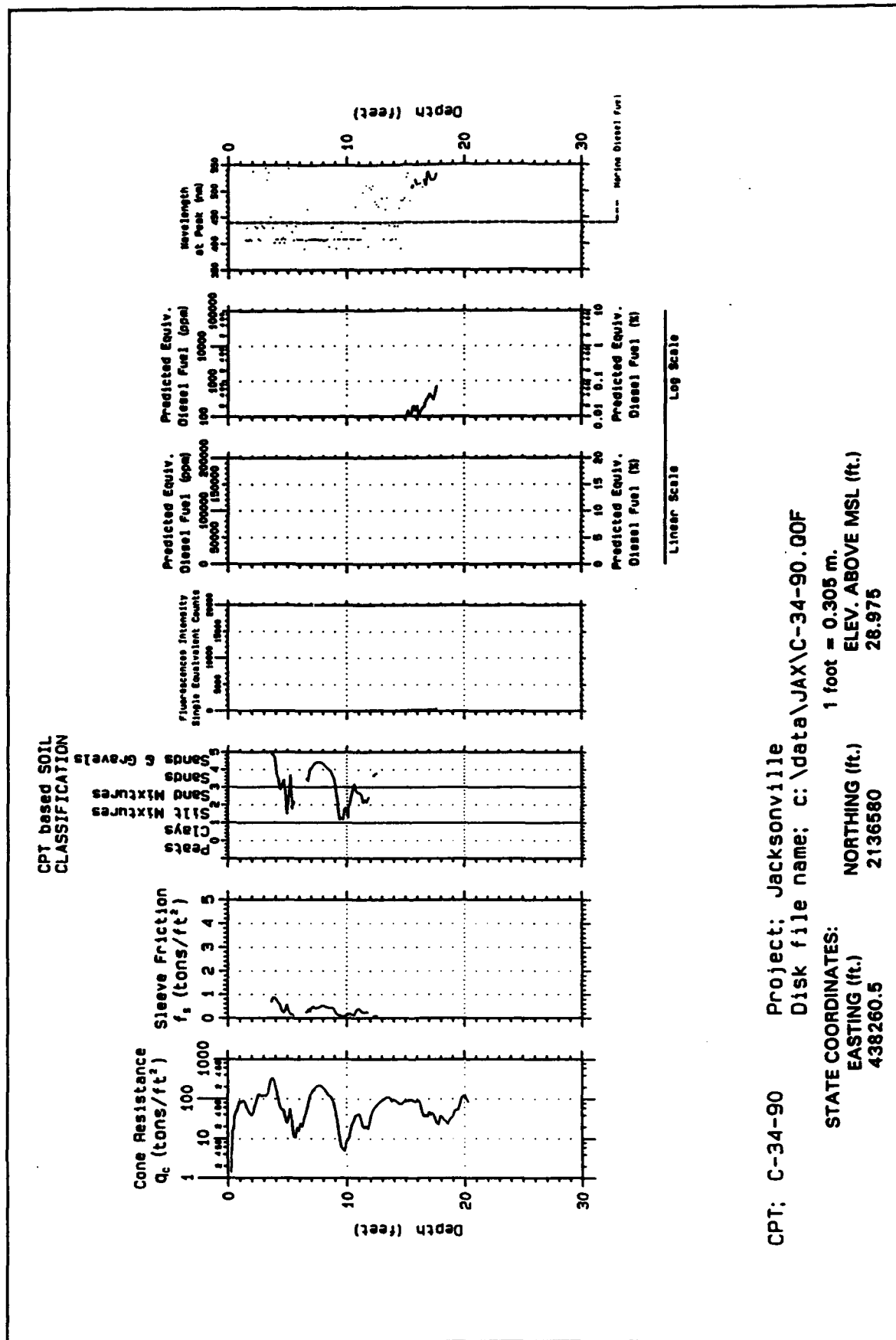


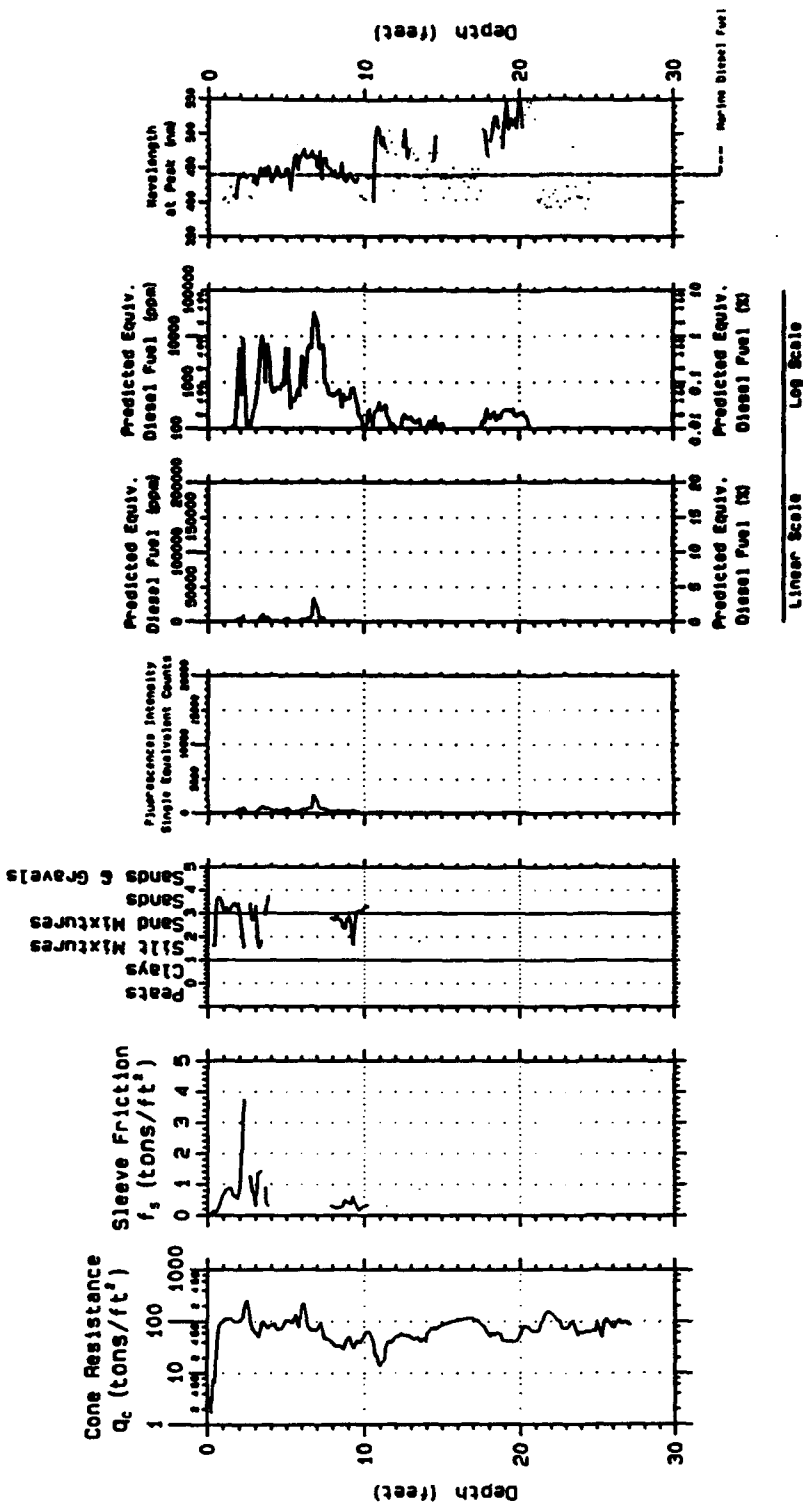
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NORTHING (ft.) 2136425



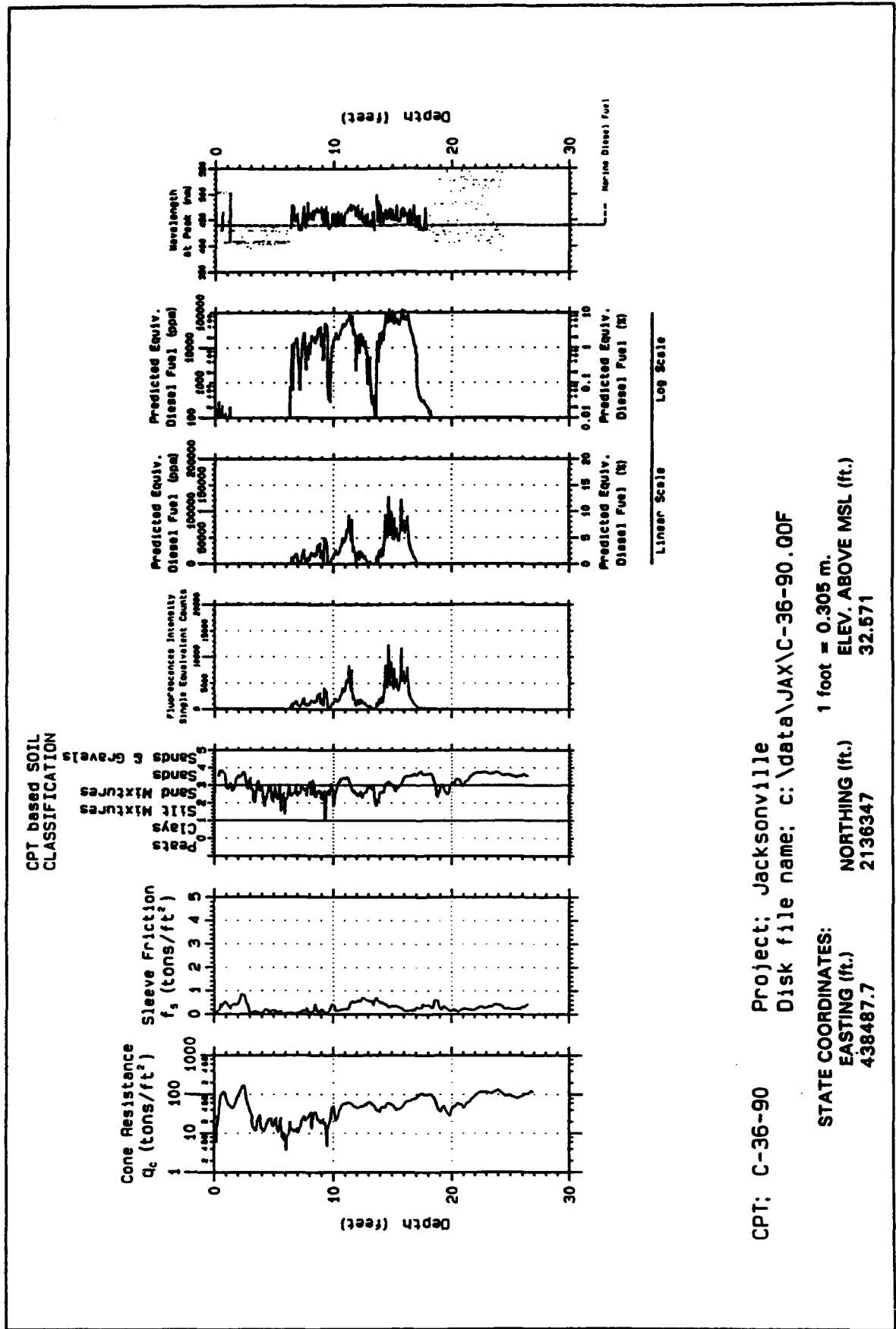


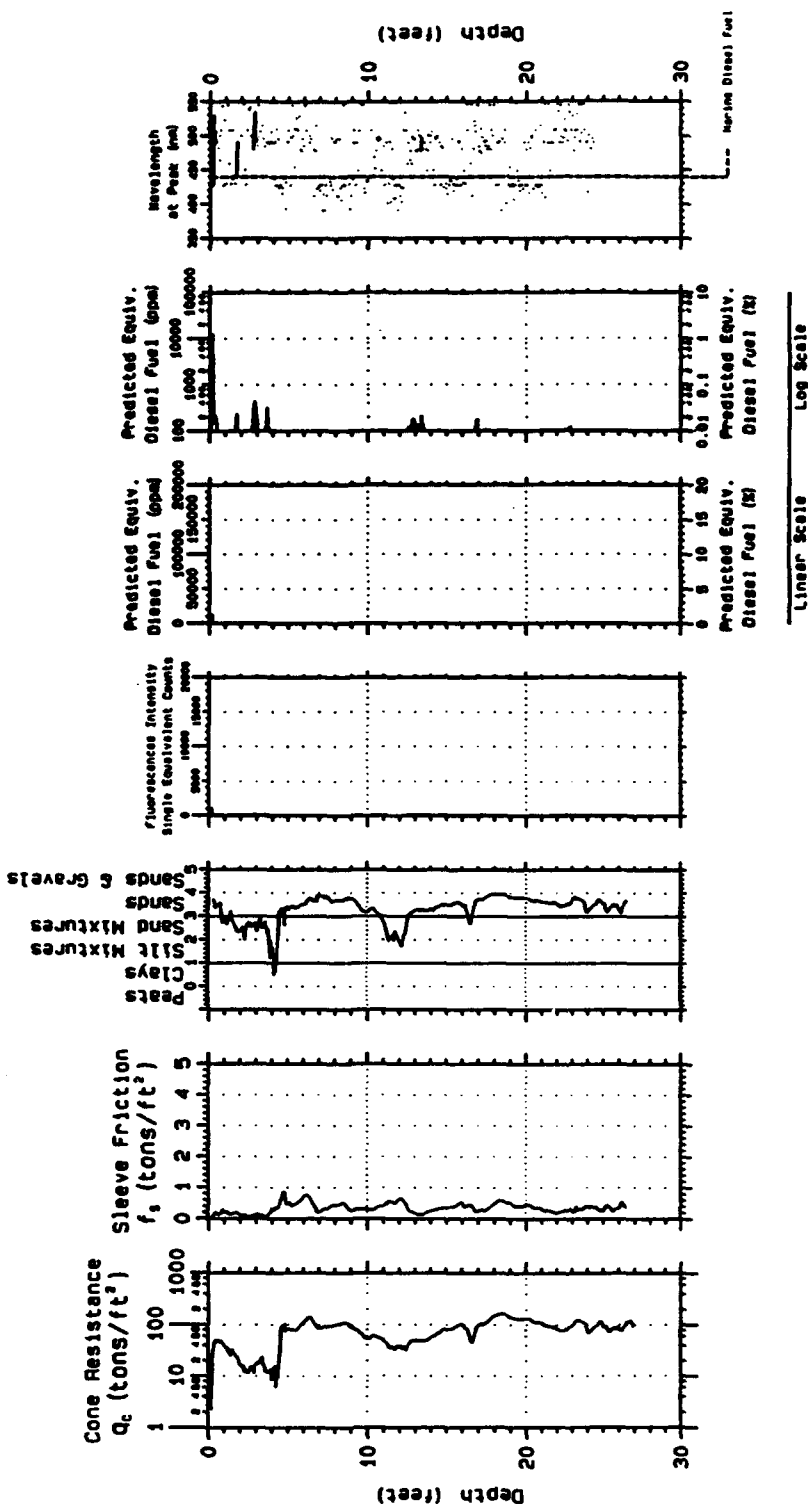


CPT based SOIL  
CLASSIFICATION

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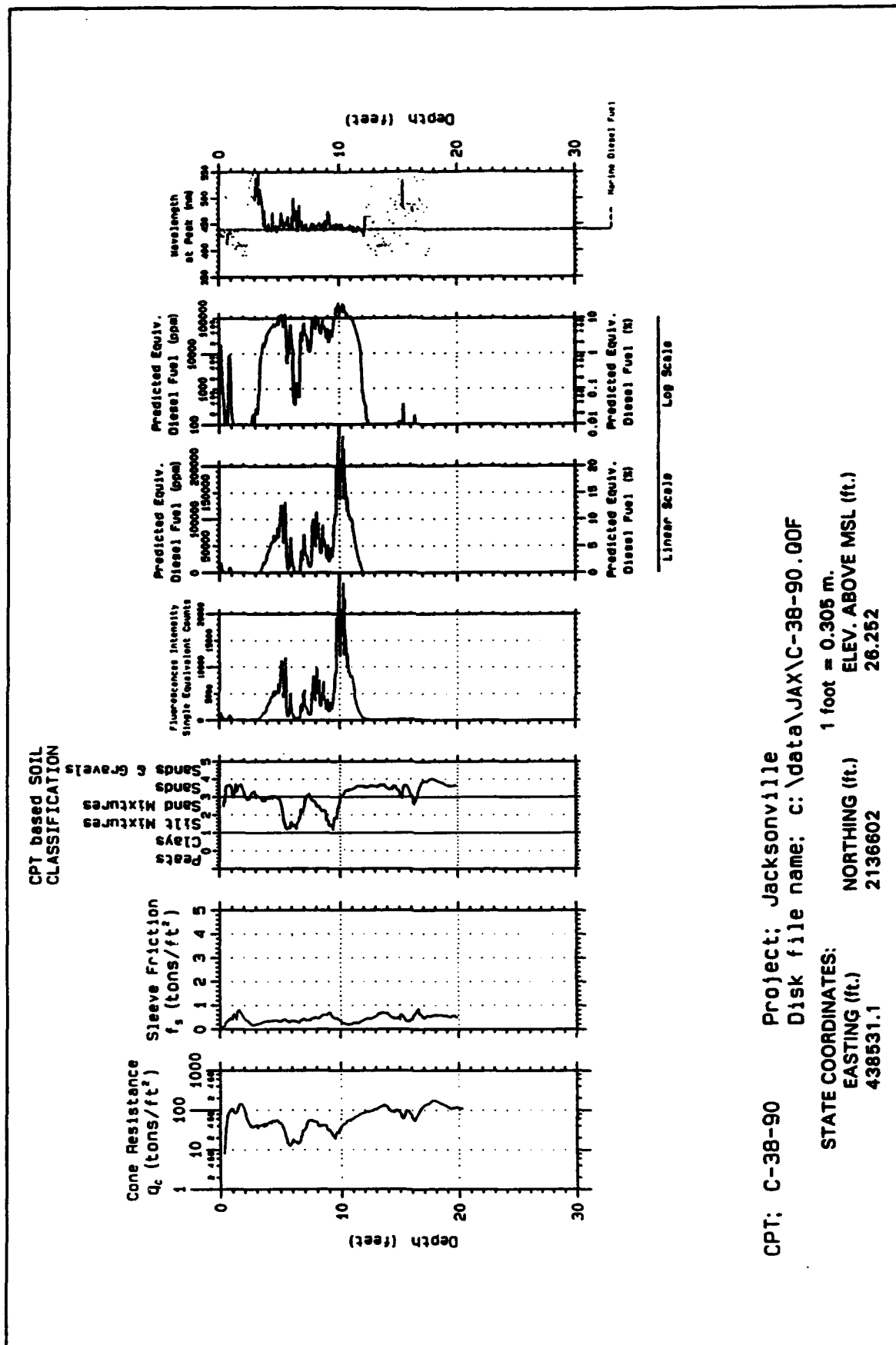
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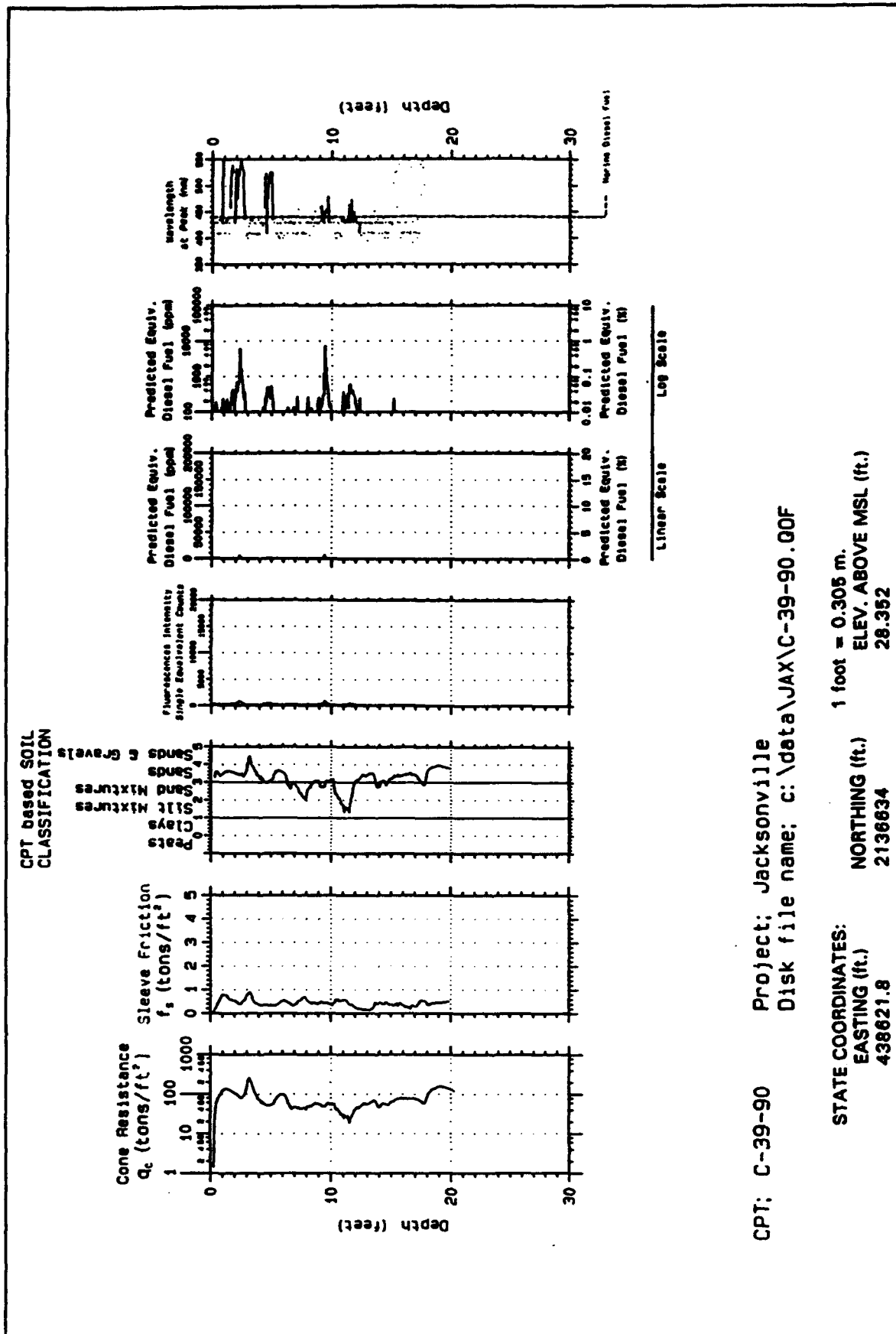
CPT based SOIL  
CLASSIFICATION

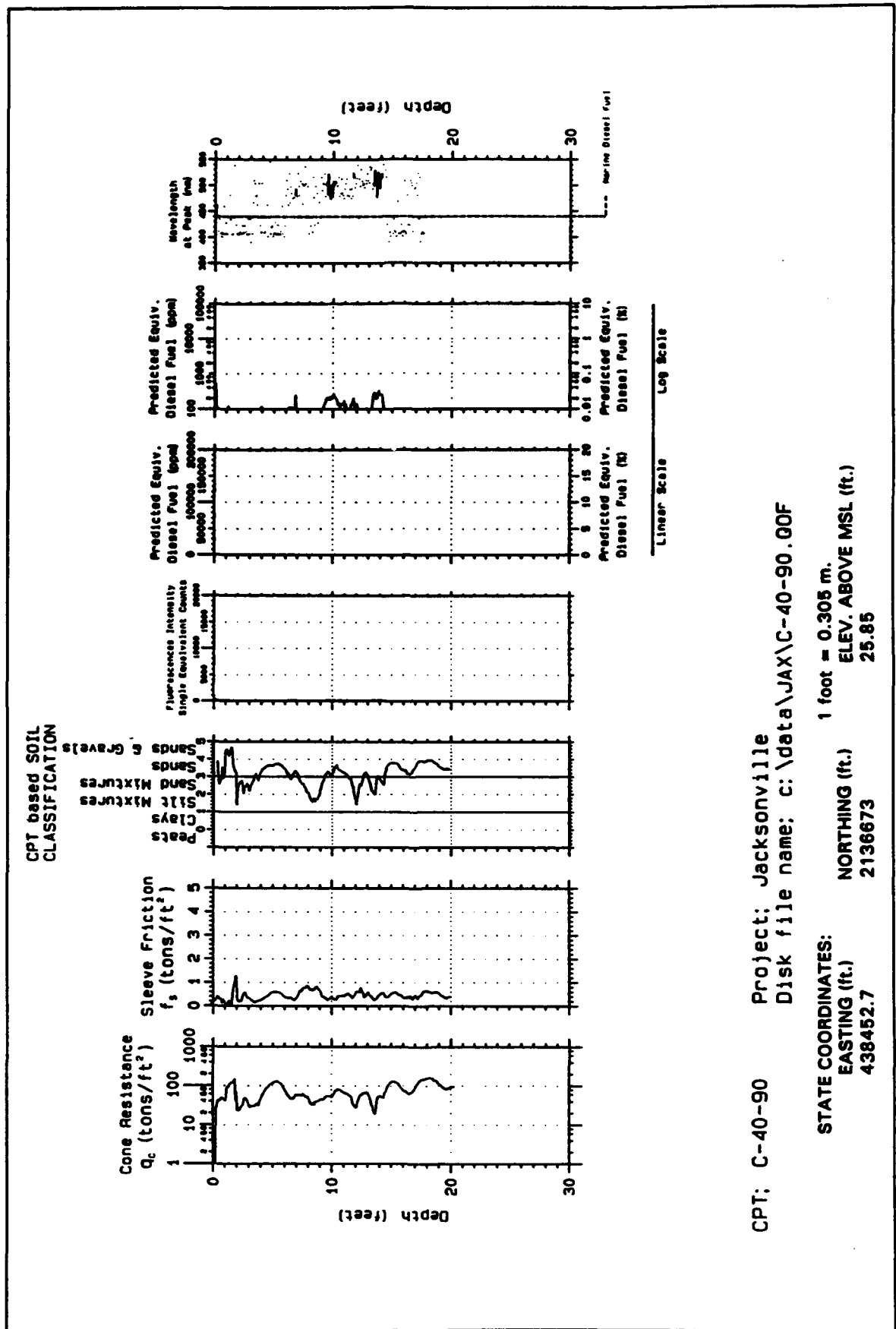
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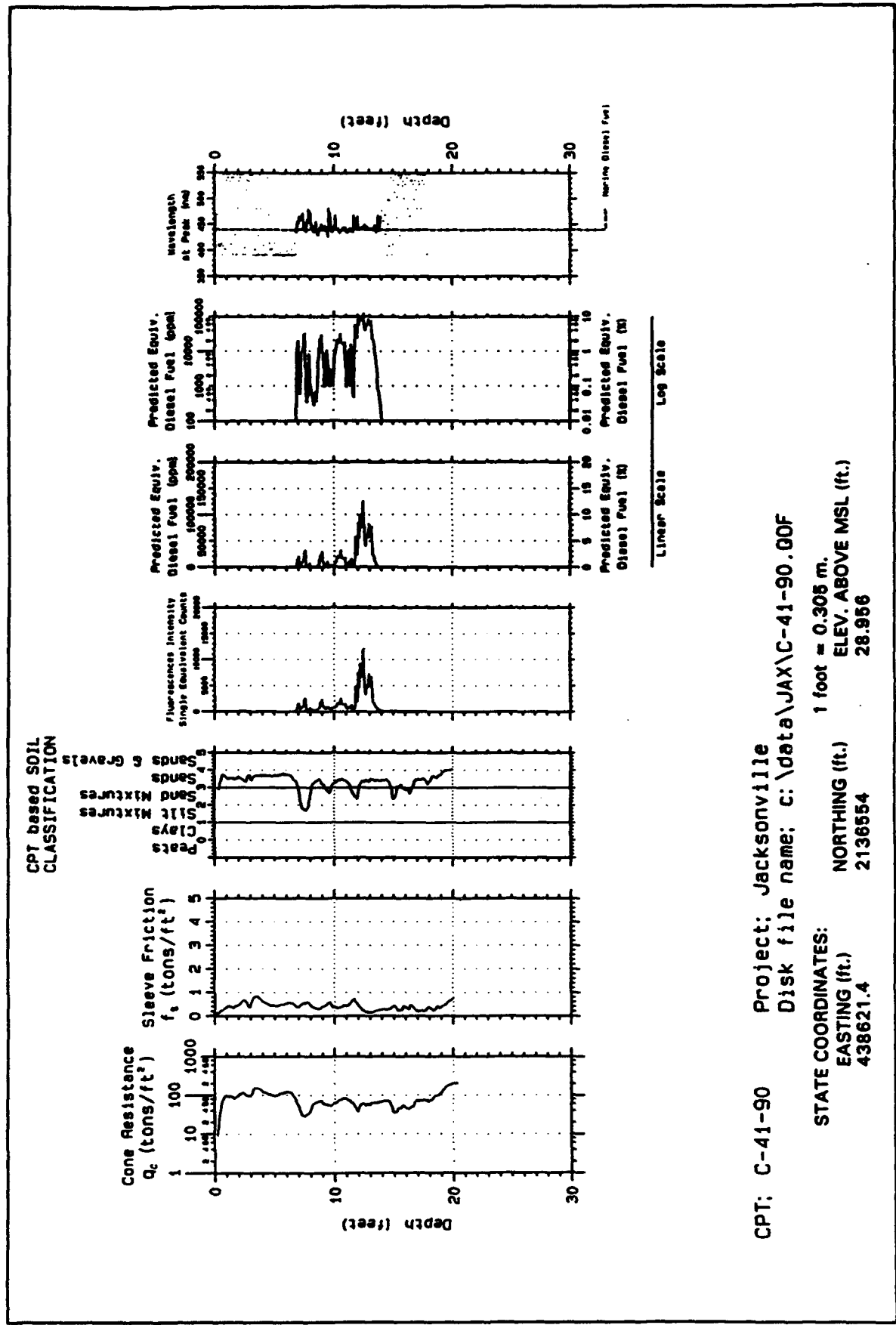
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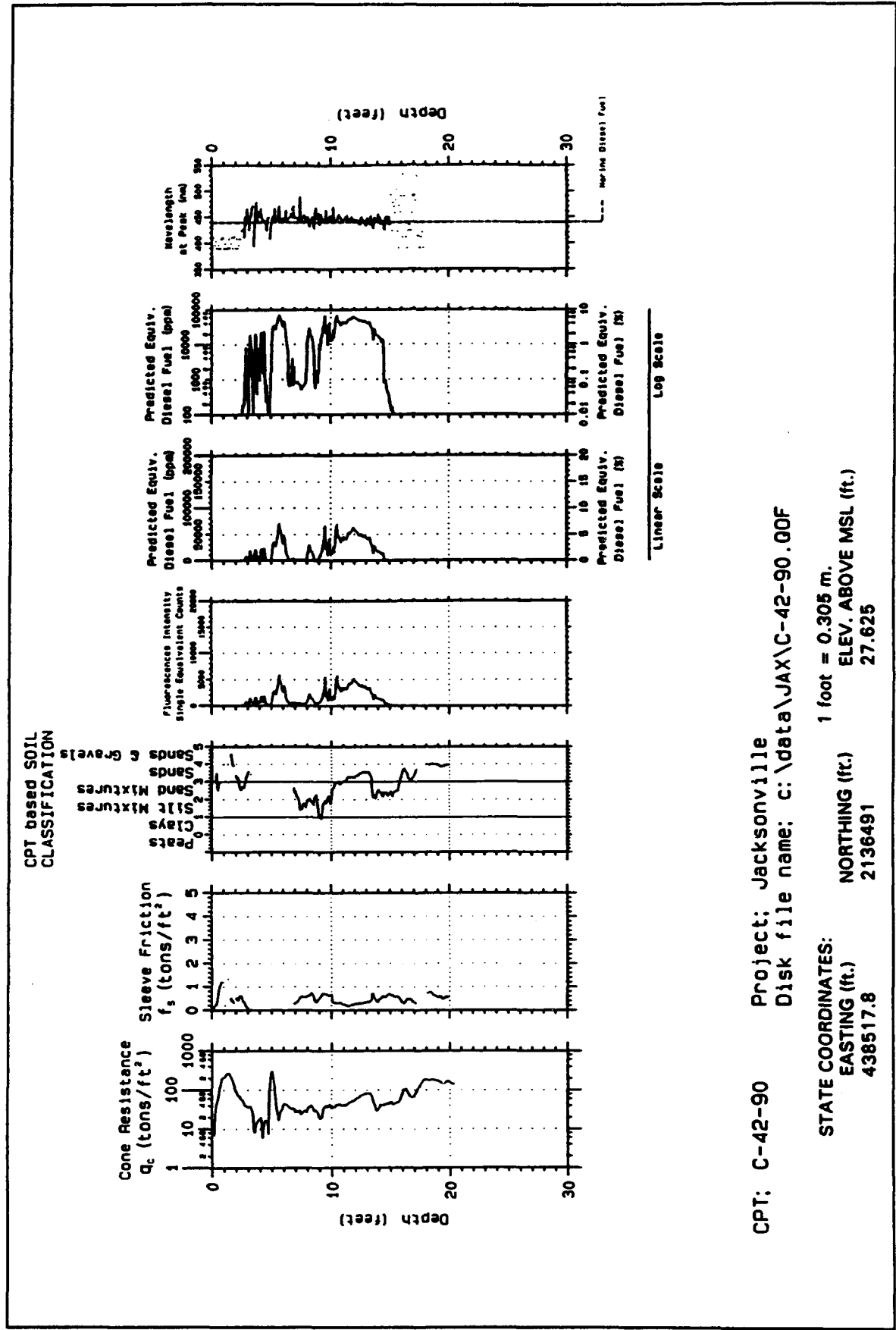


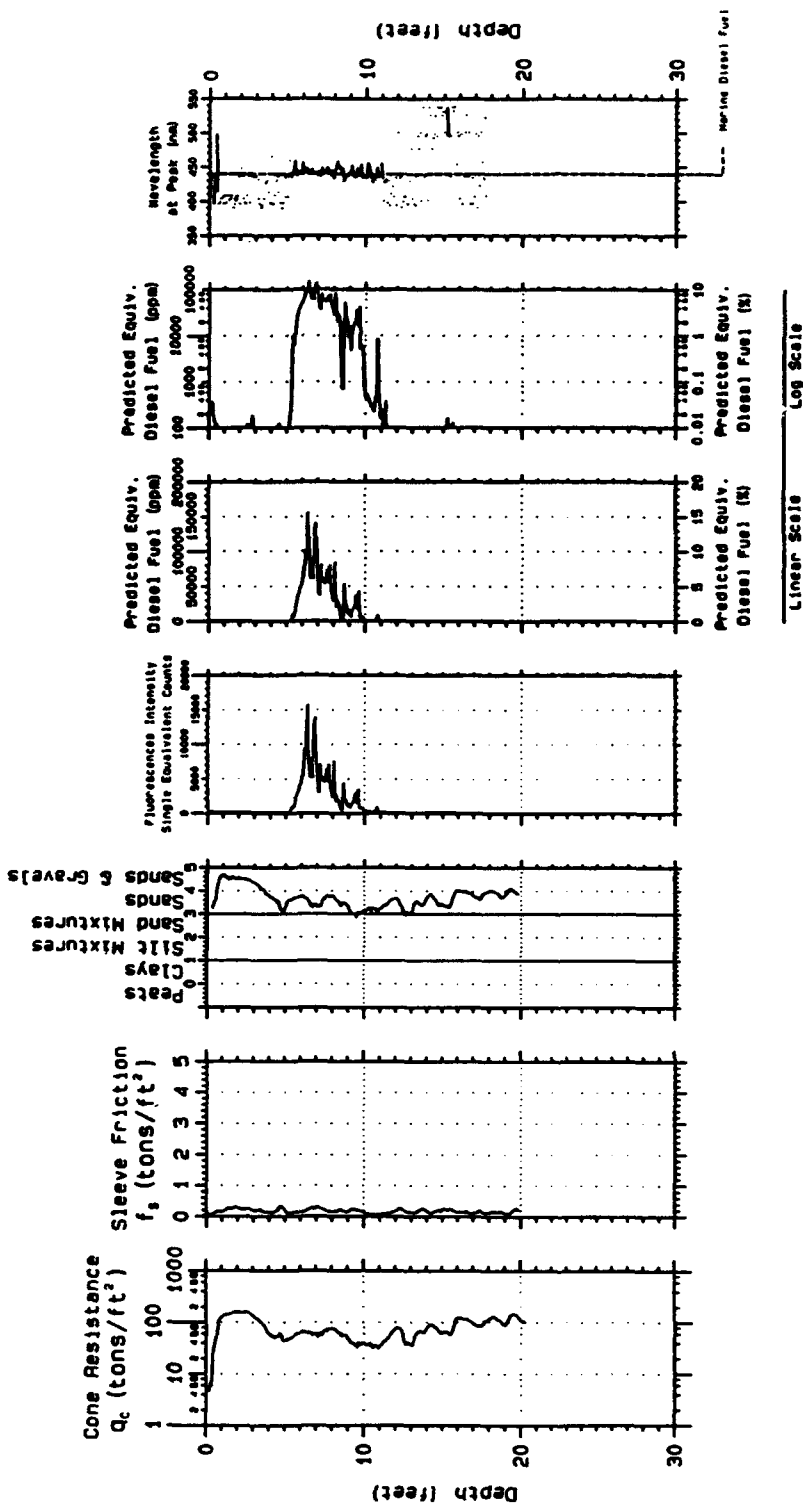
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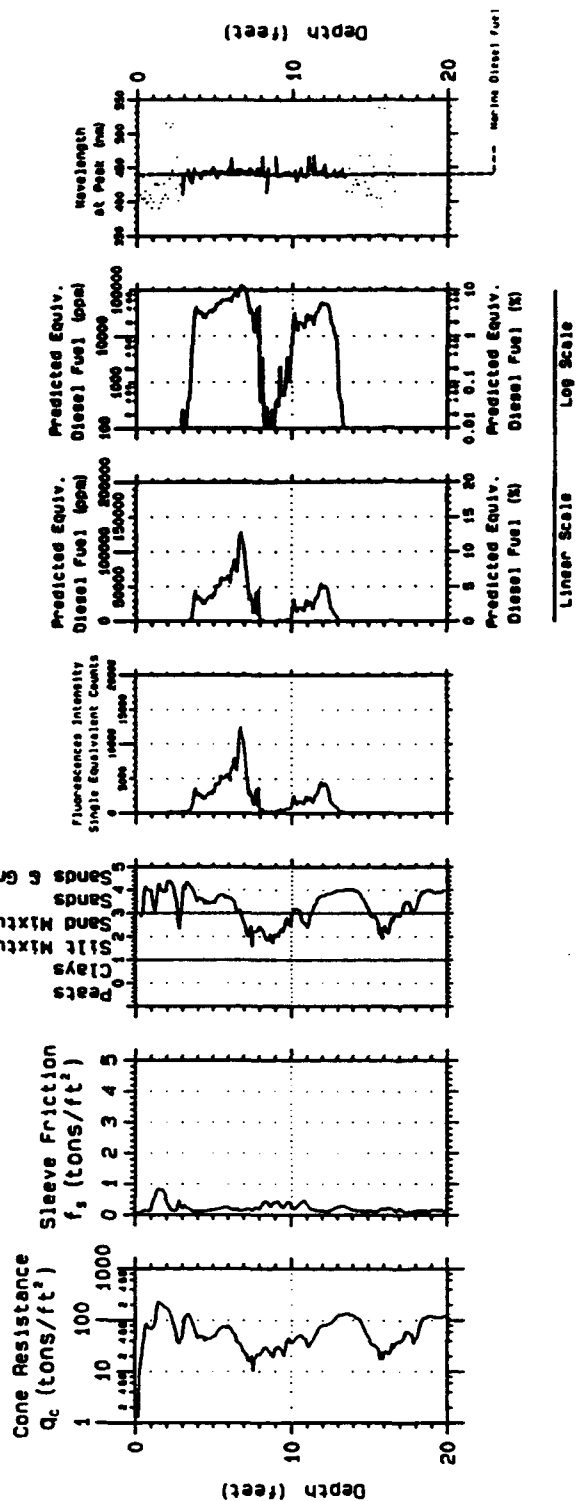


CPT based SOIL  
CLASSIFICATION

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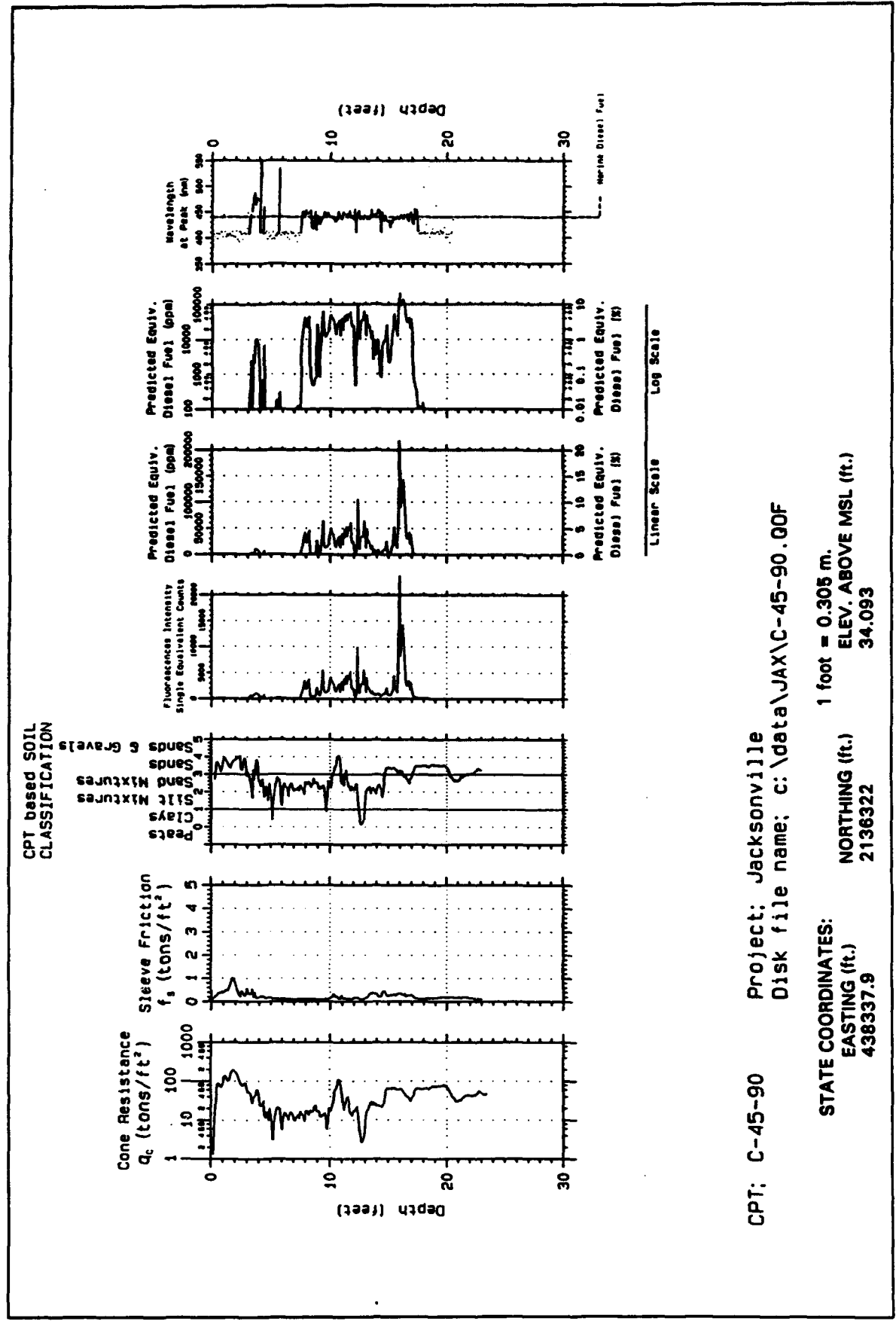
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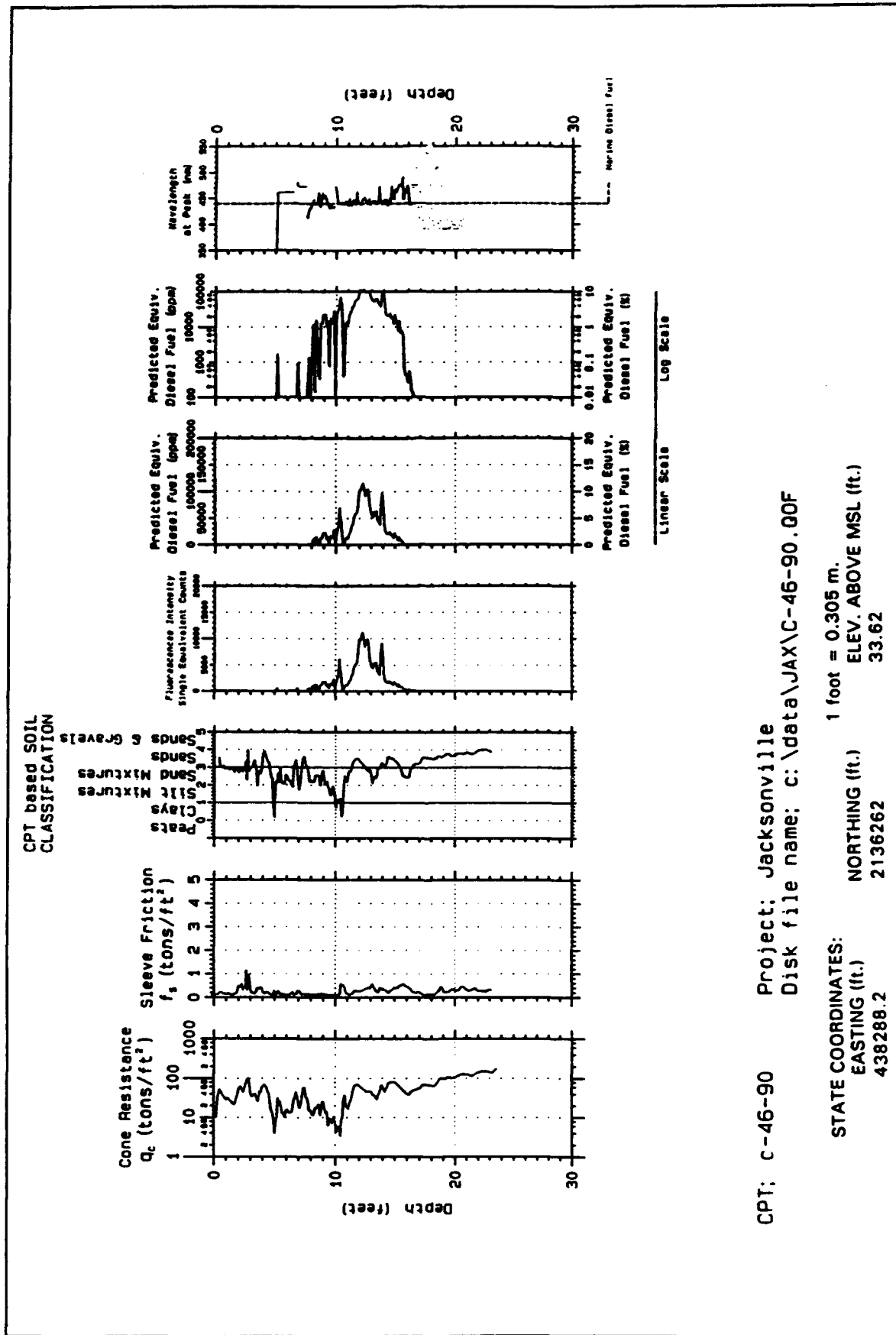
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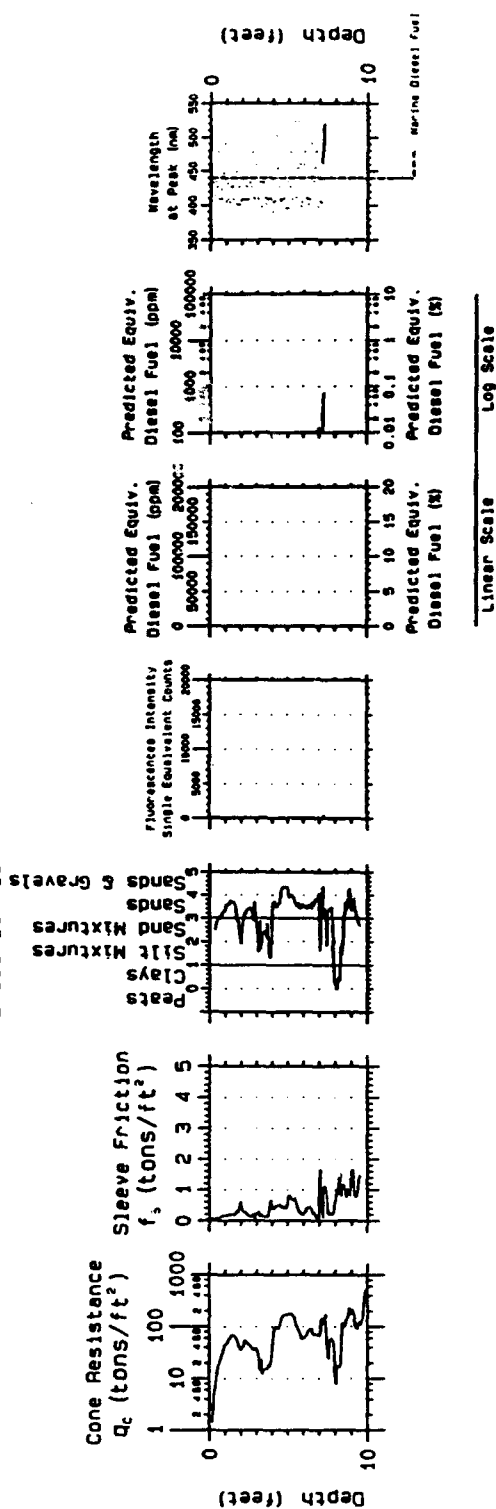


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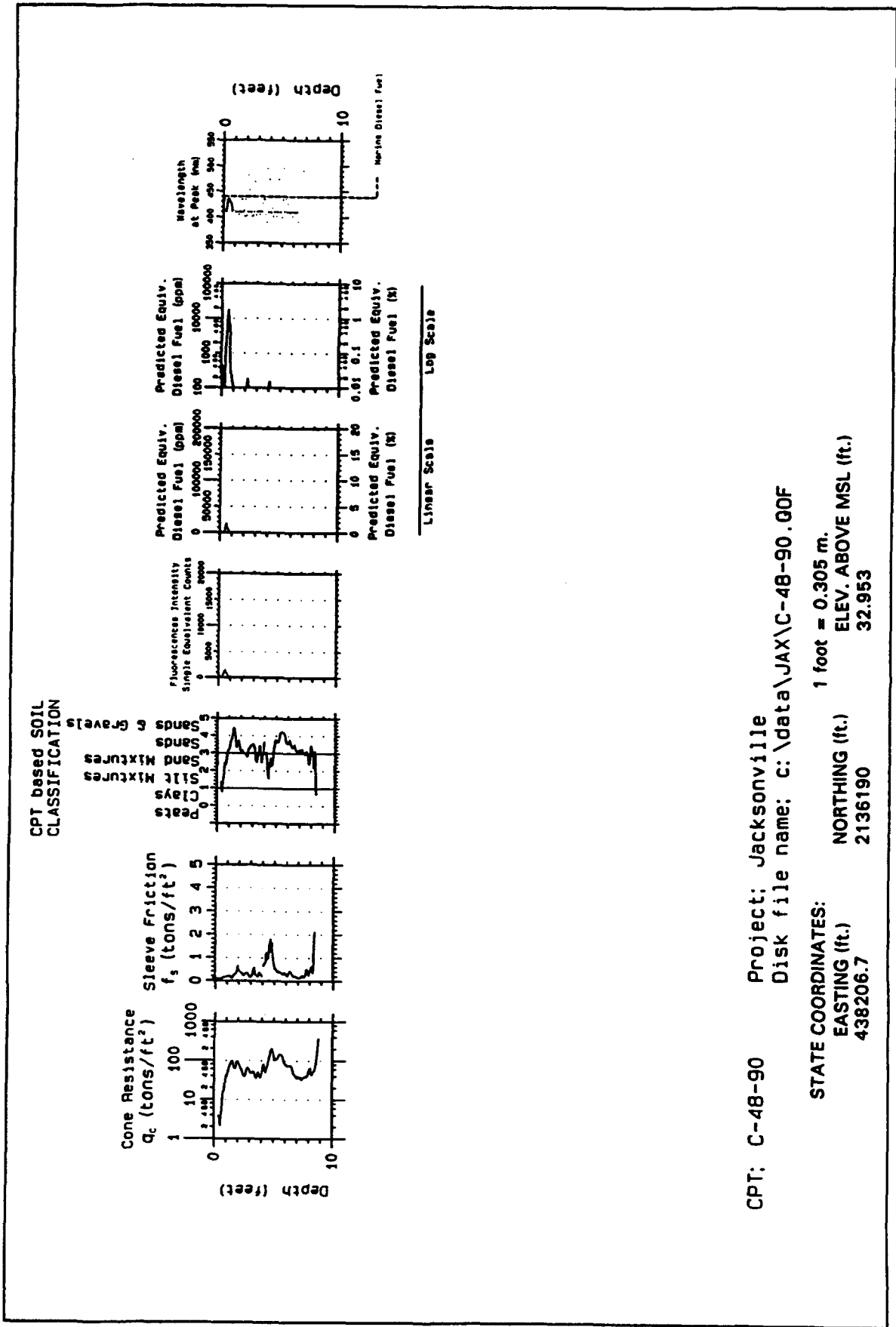


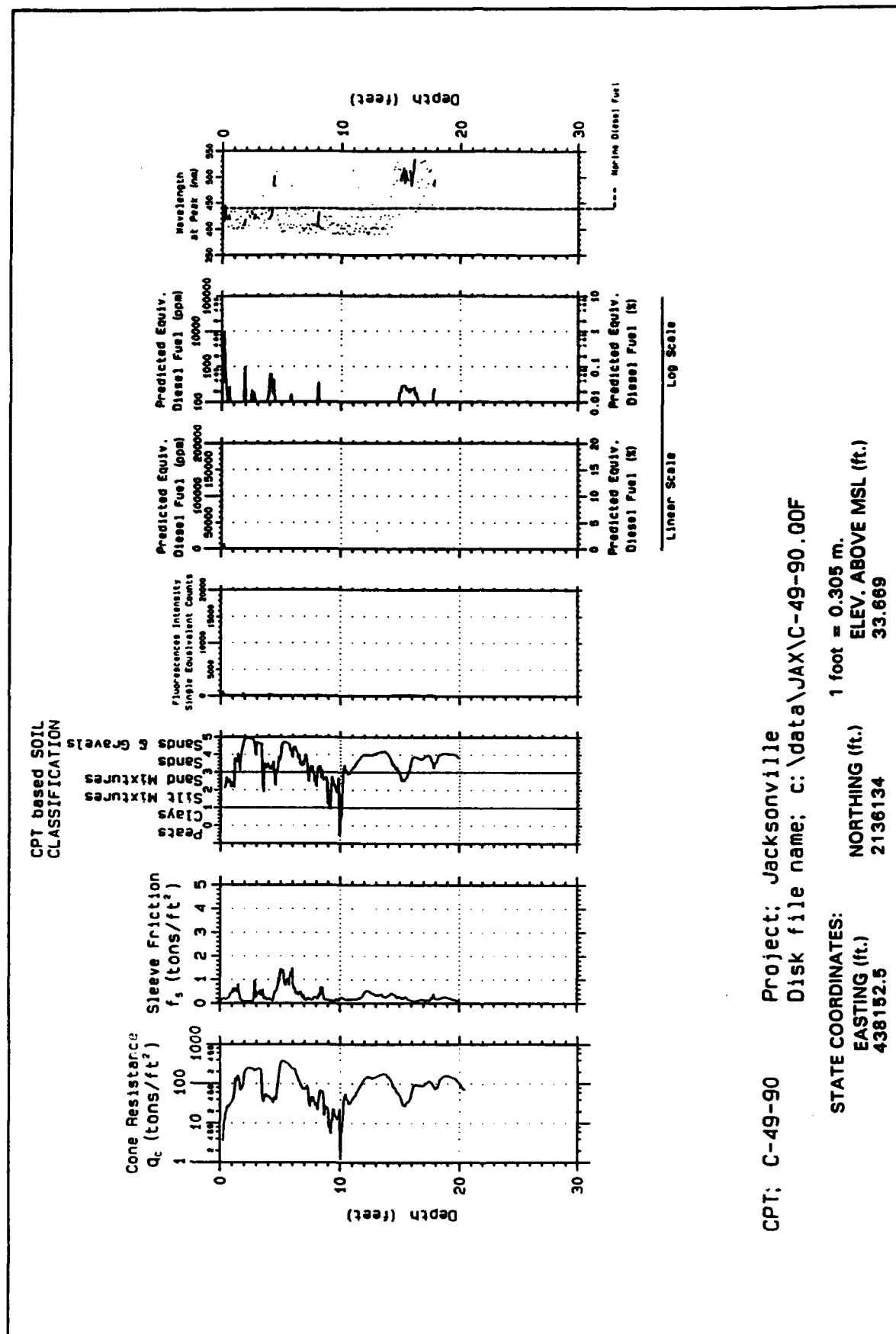


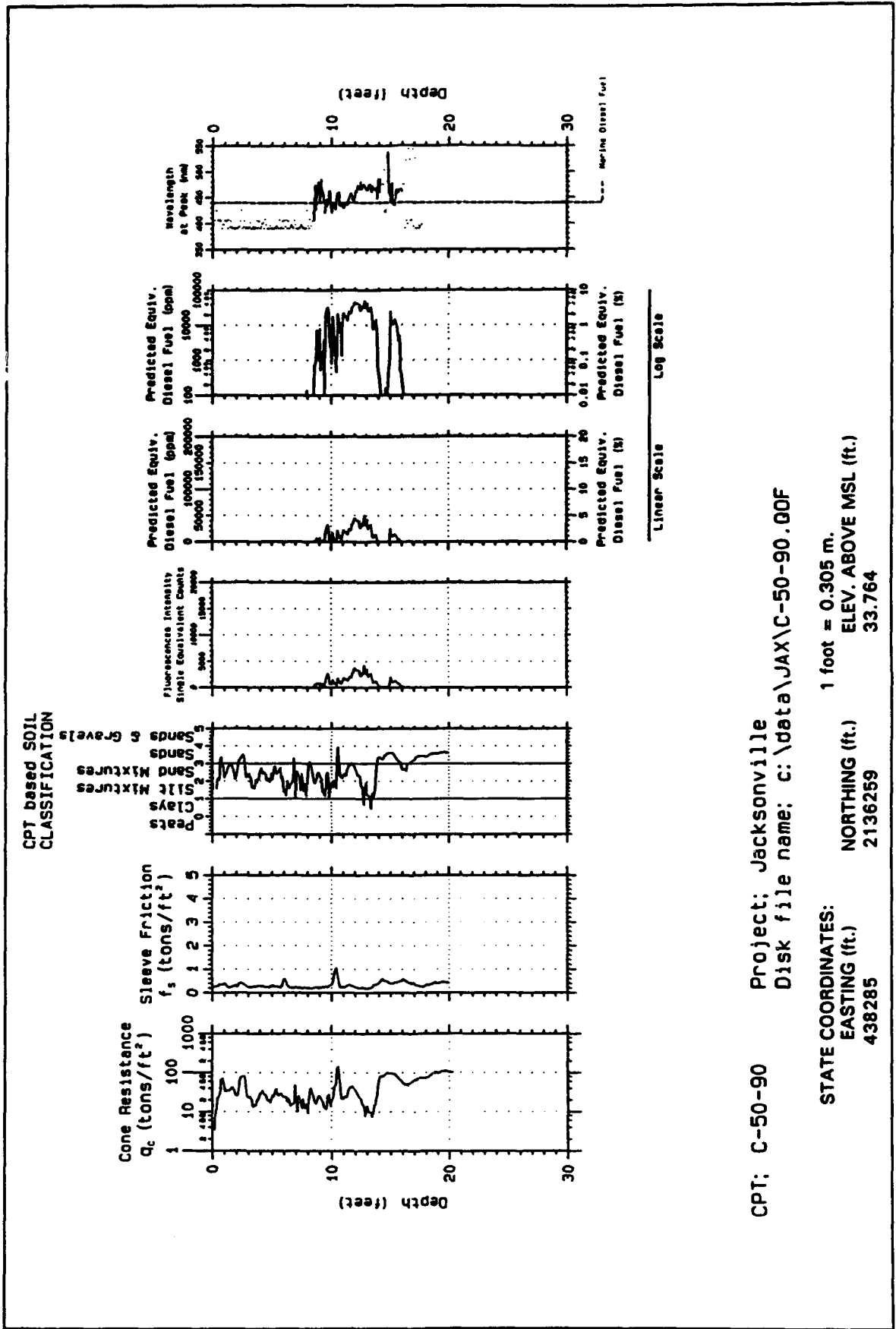
CPT based SOIL  
CLASSIFICATION

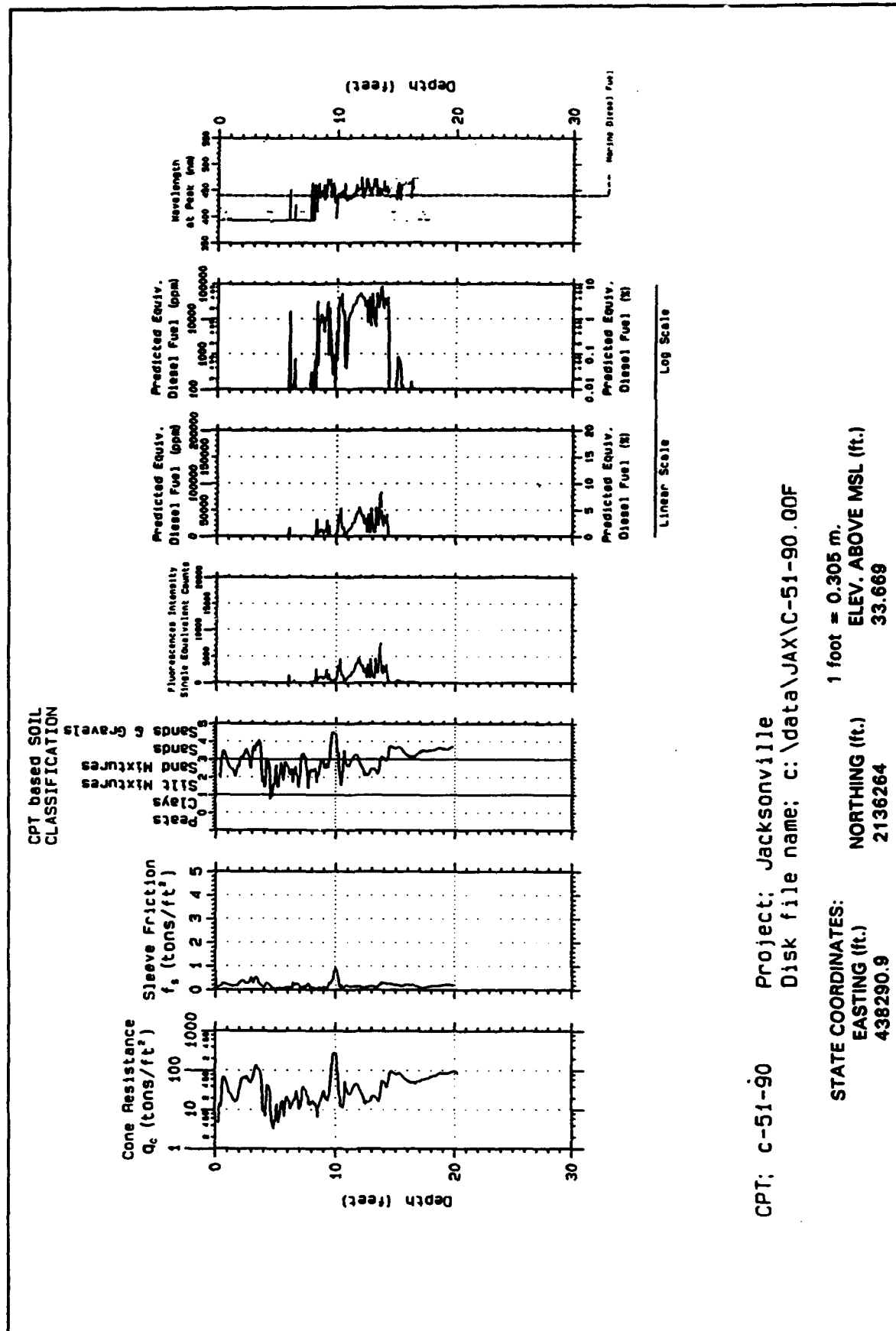
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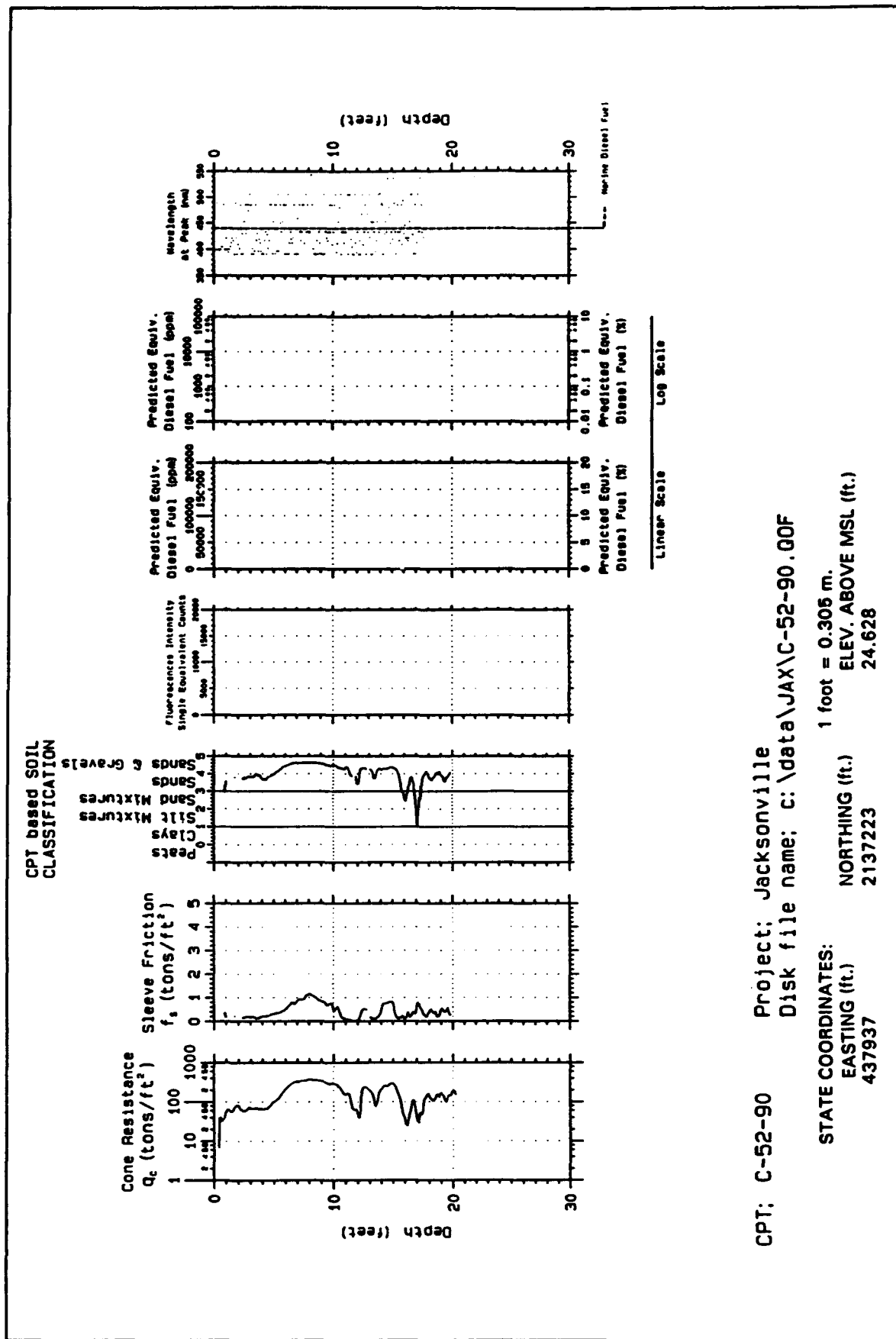
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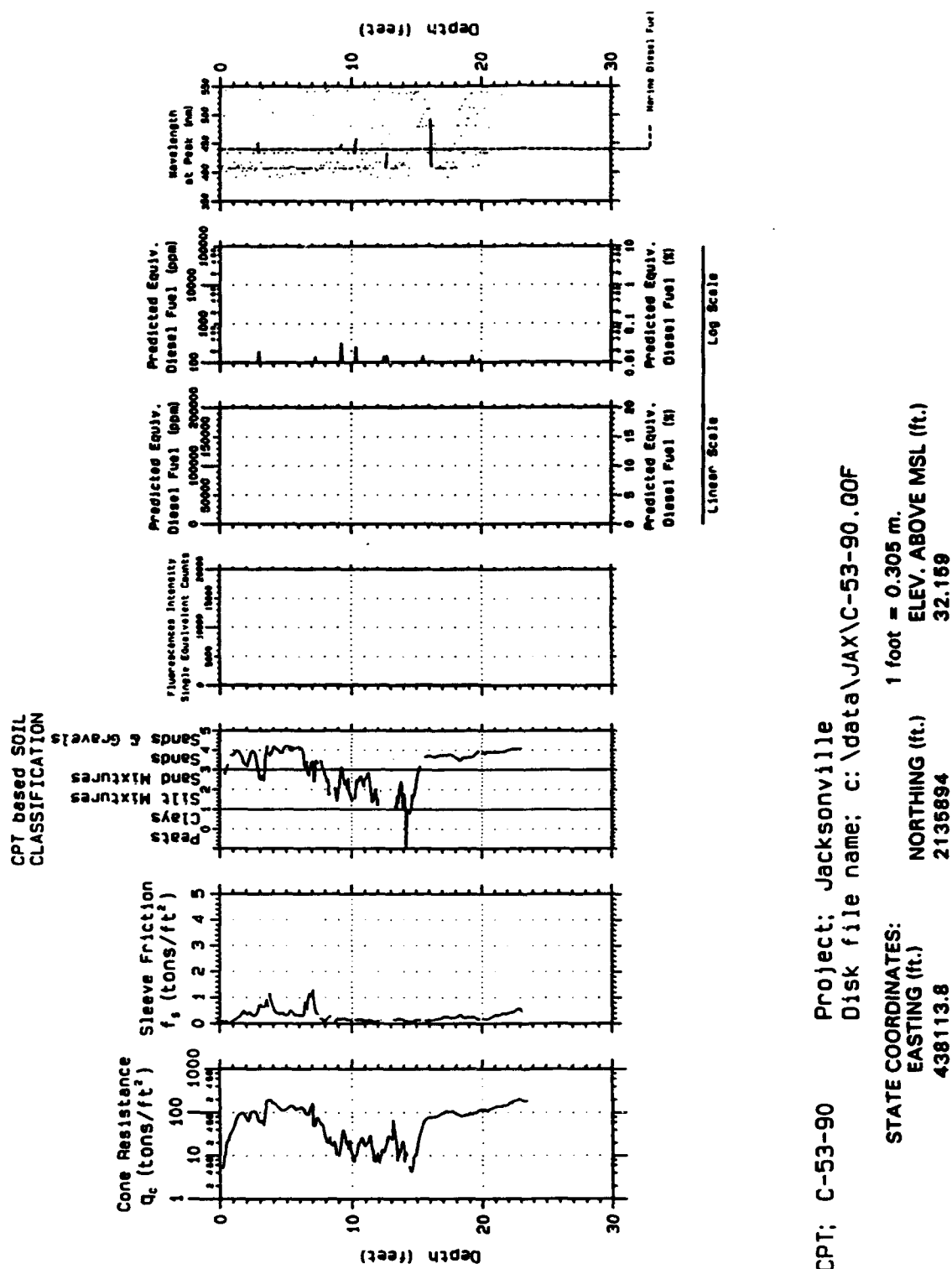


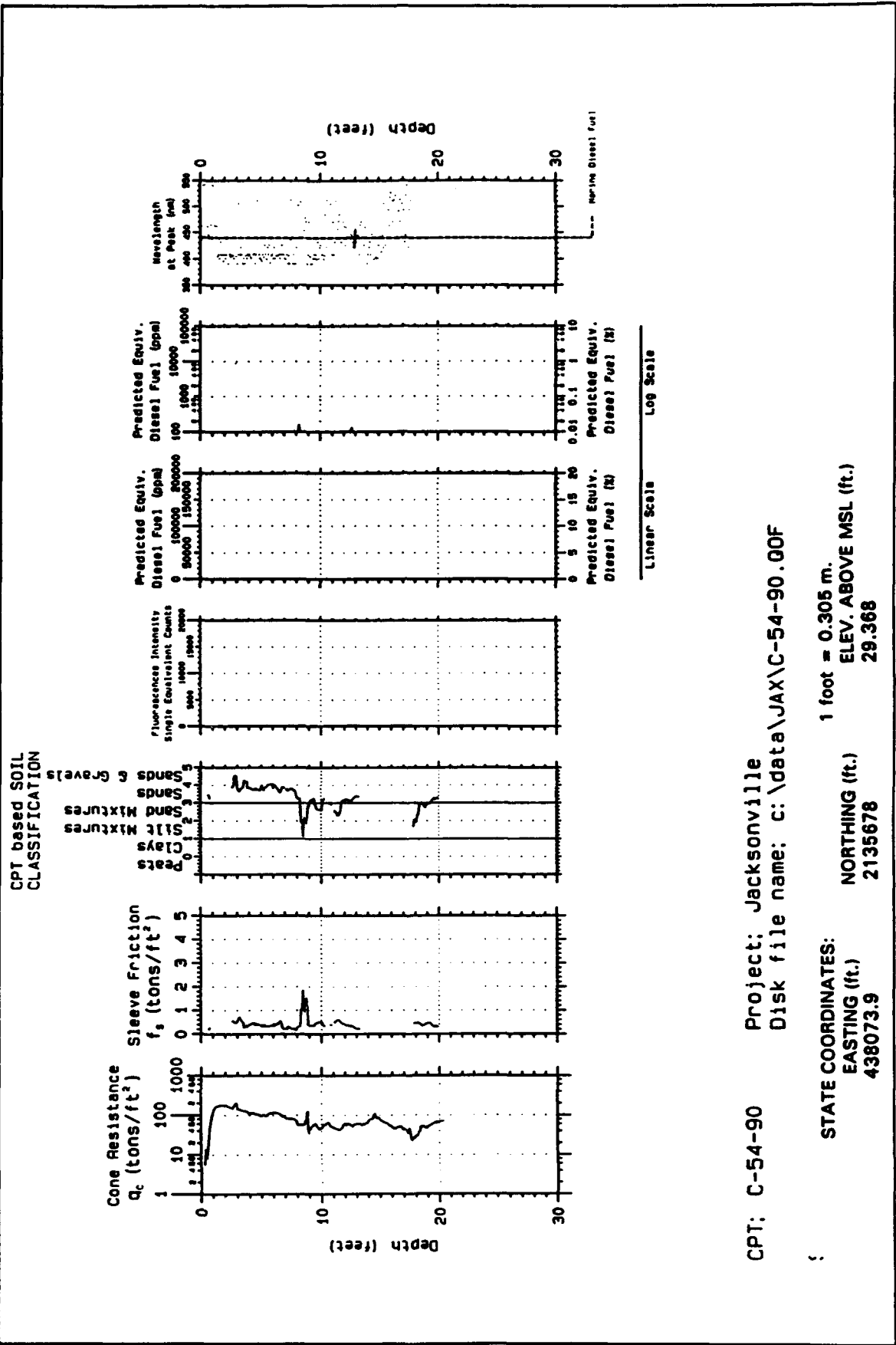


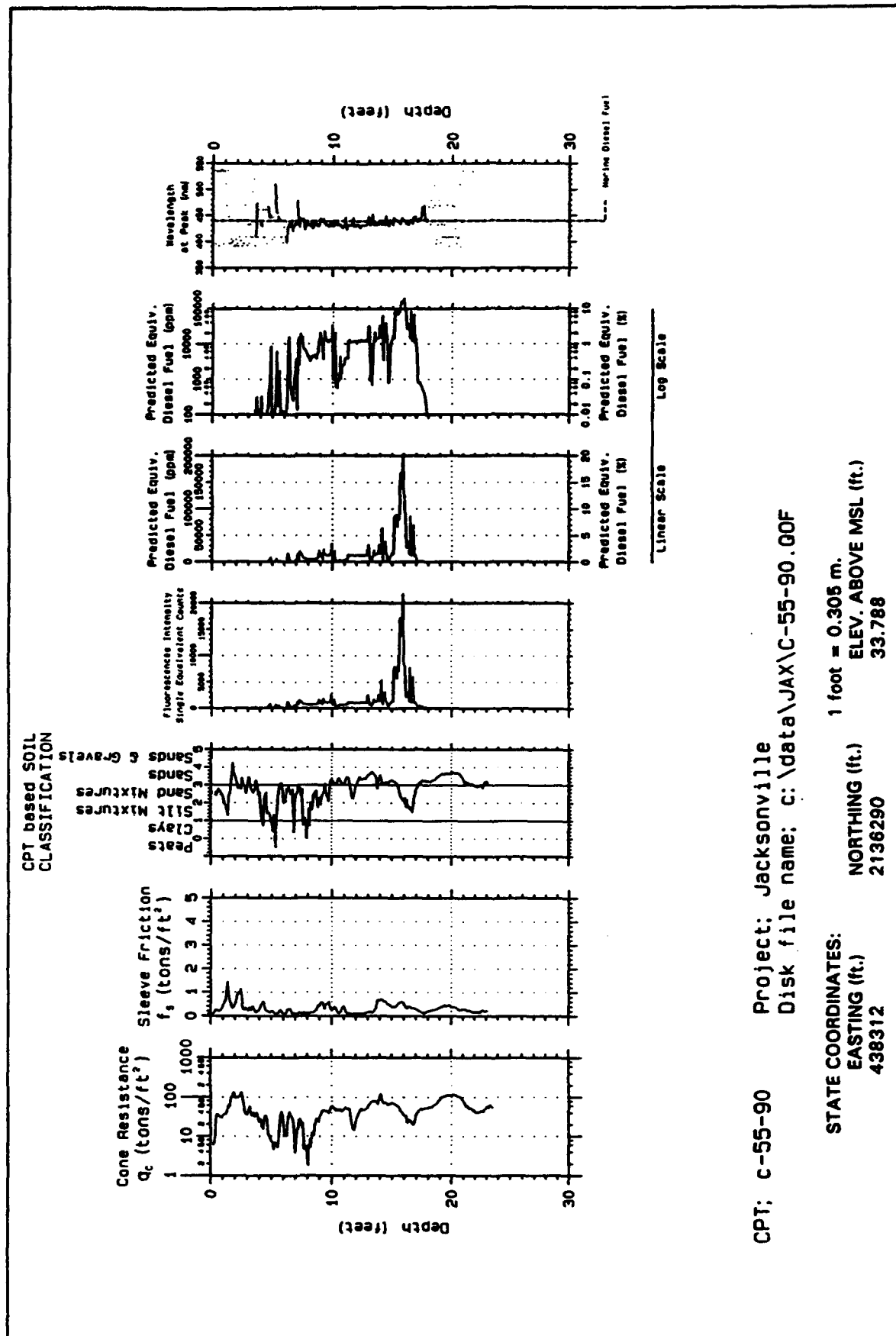


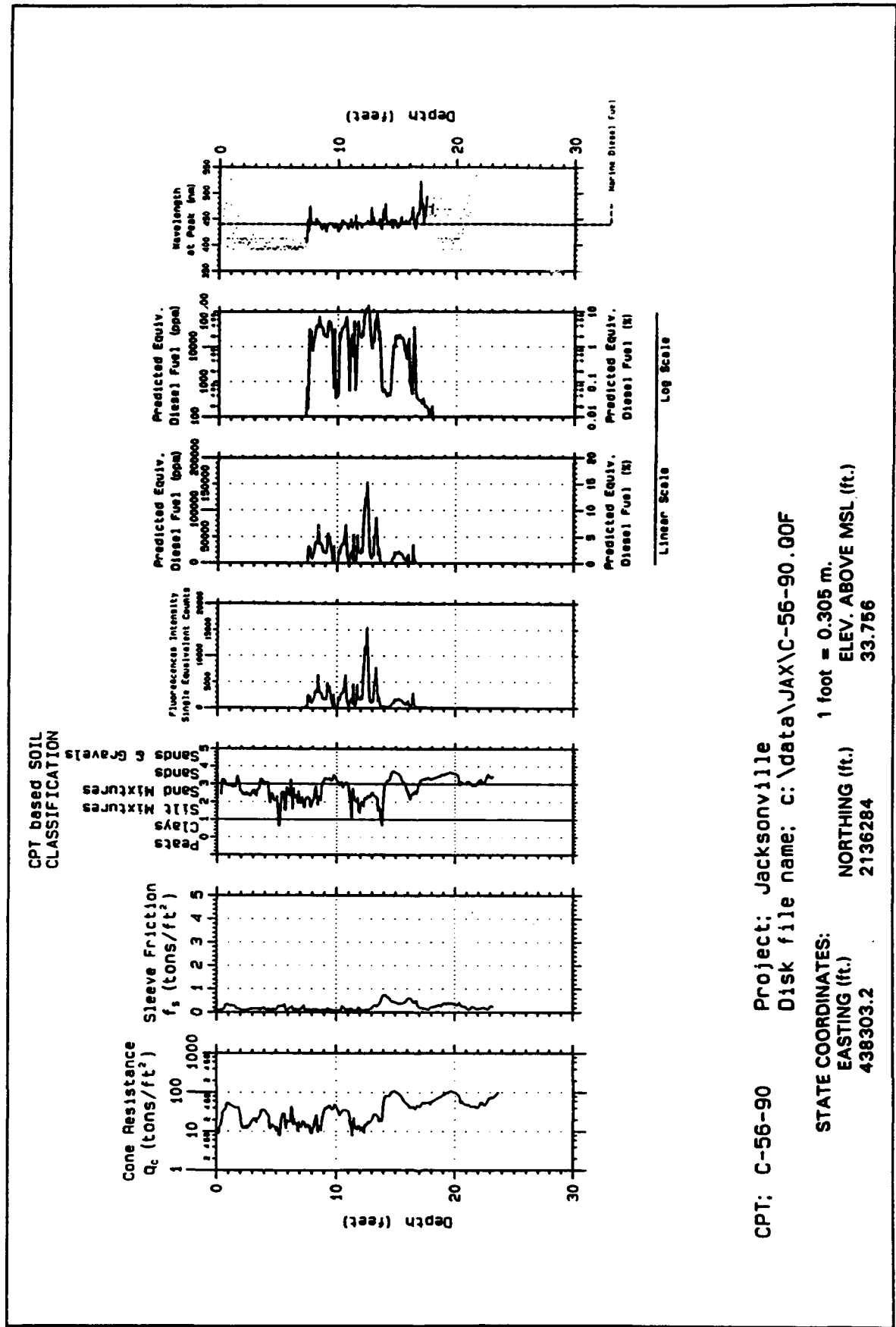


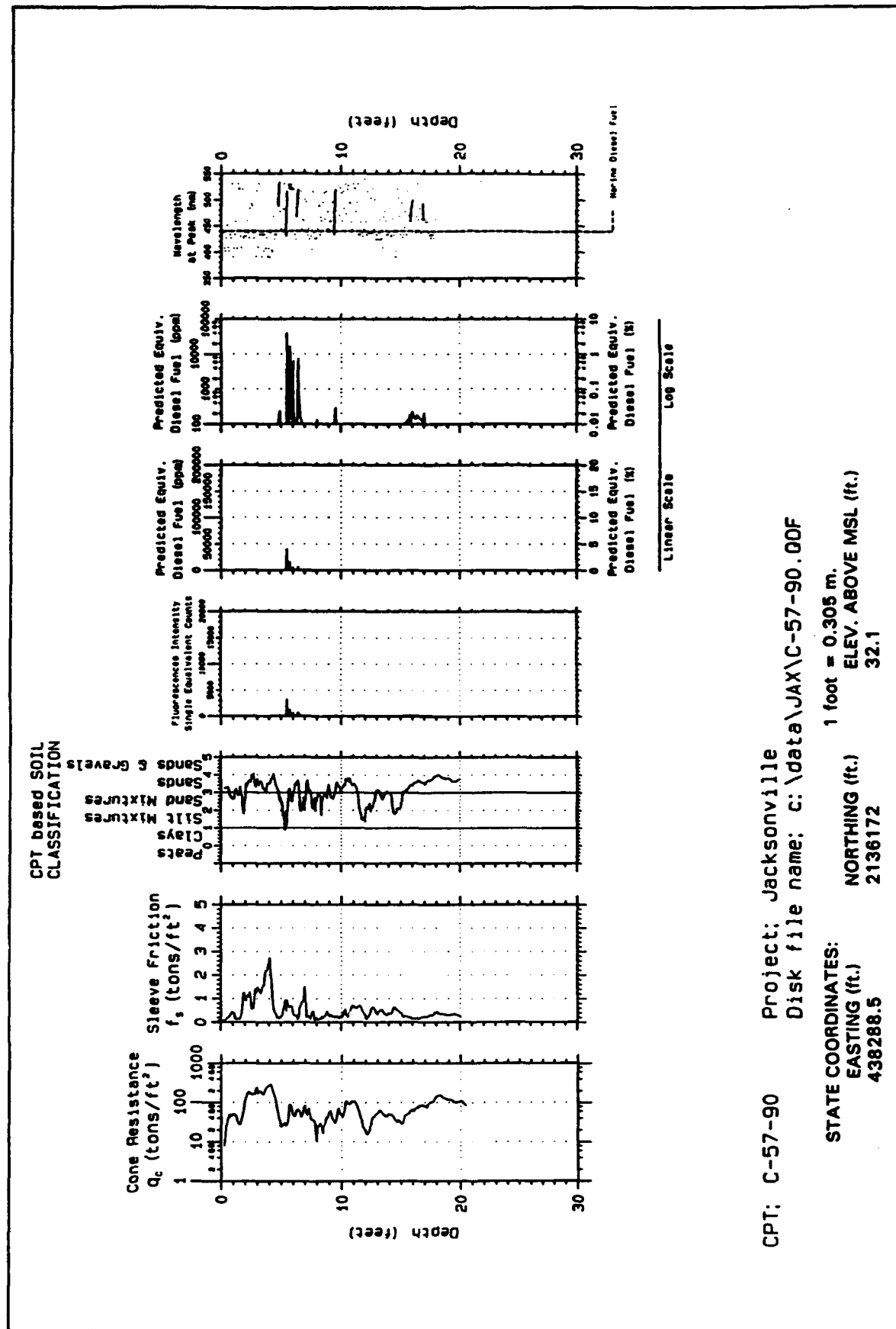


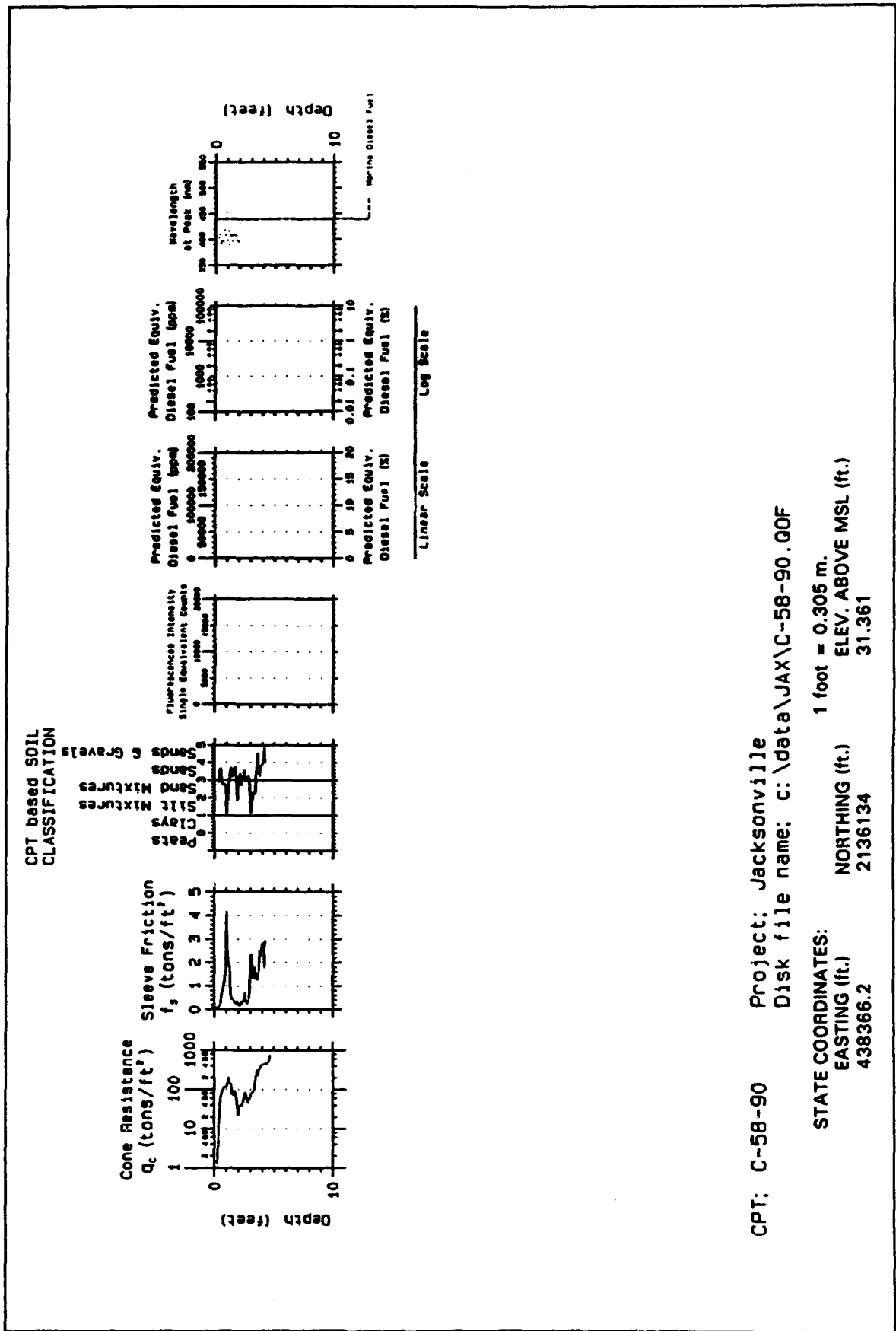


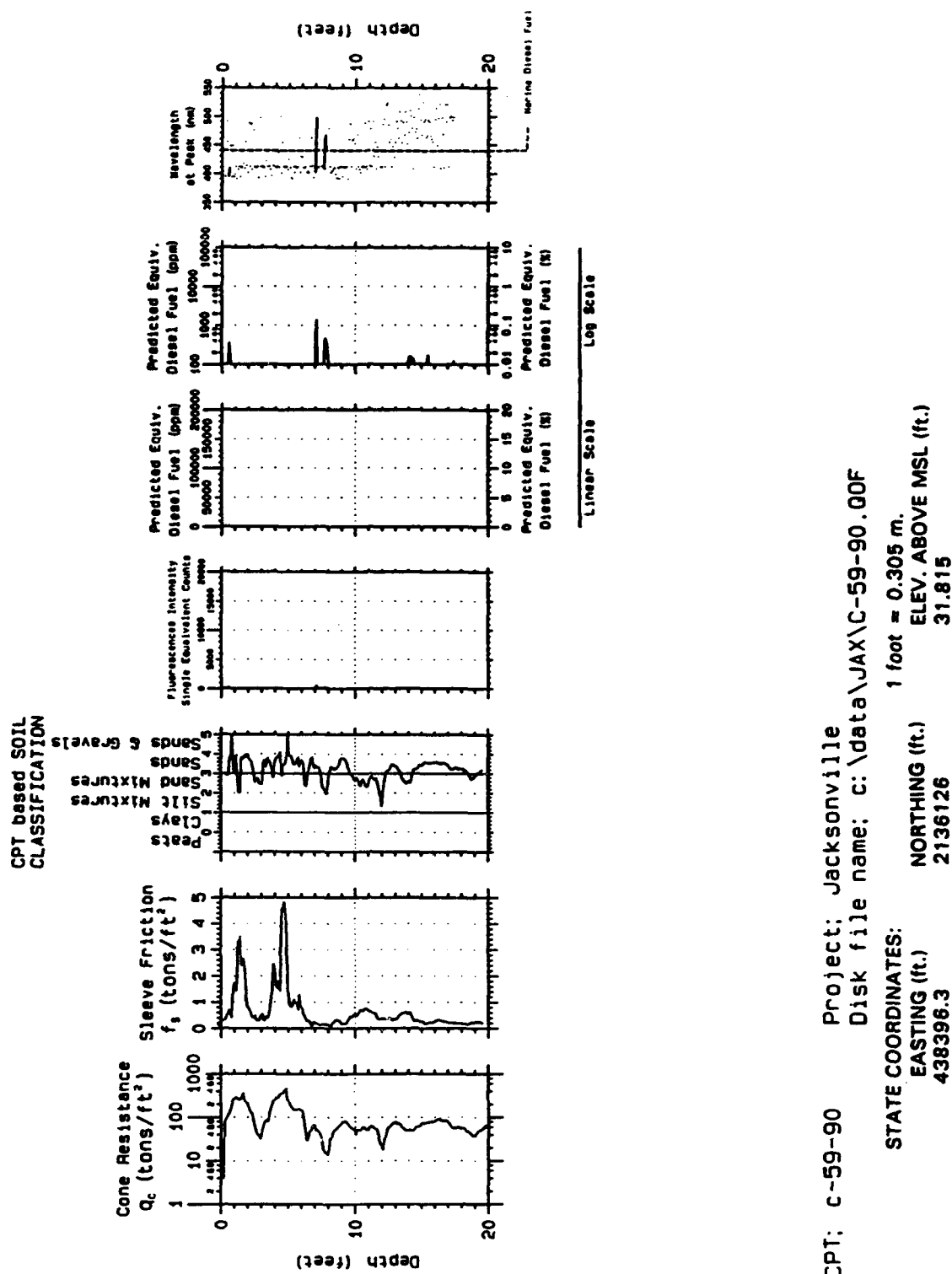


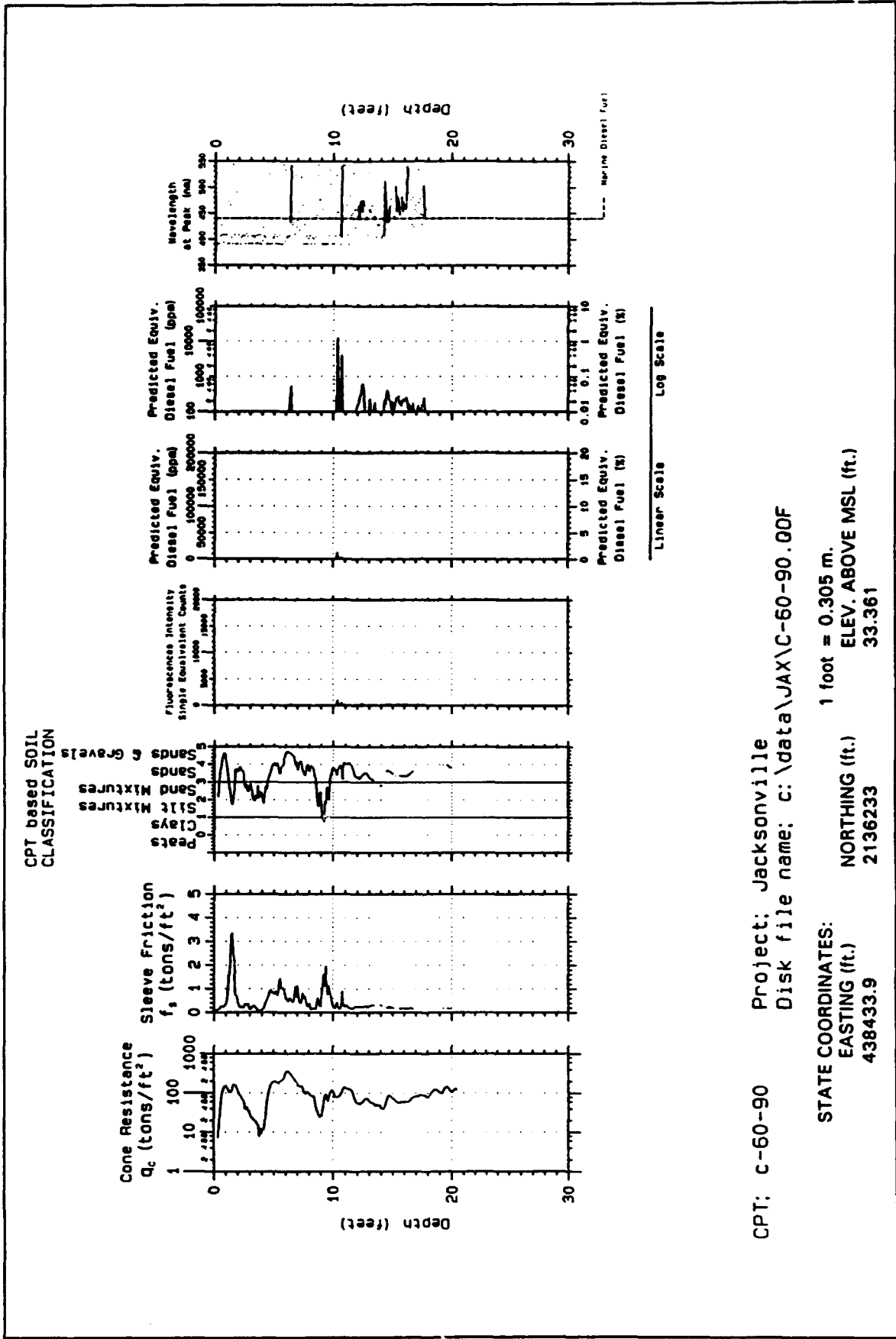


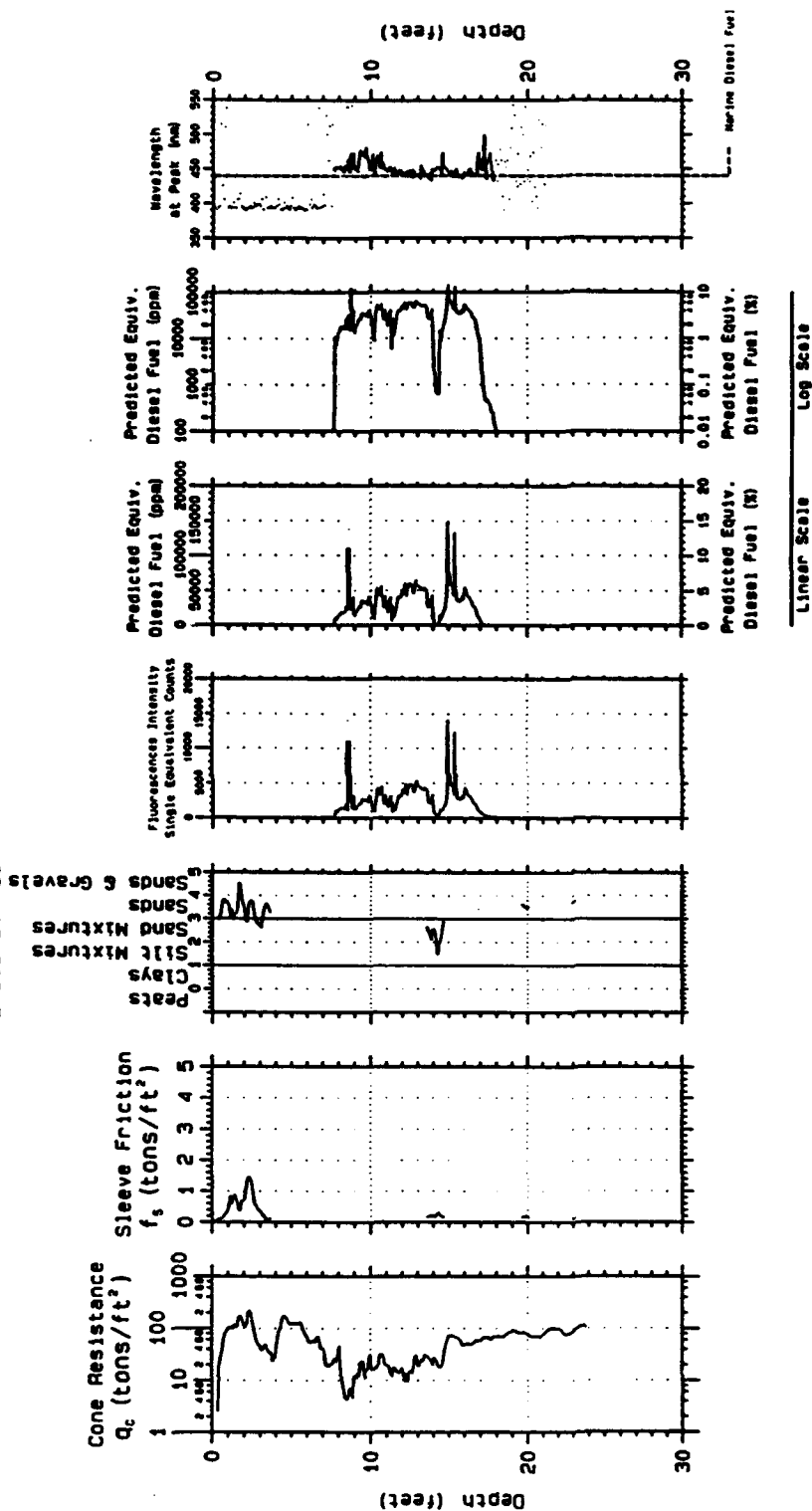








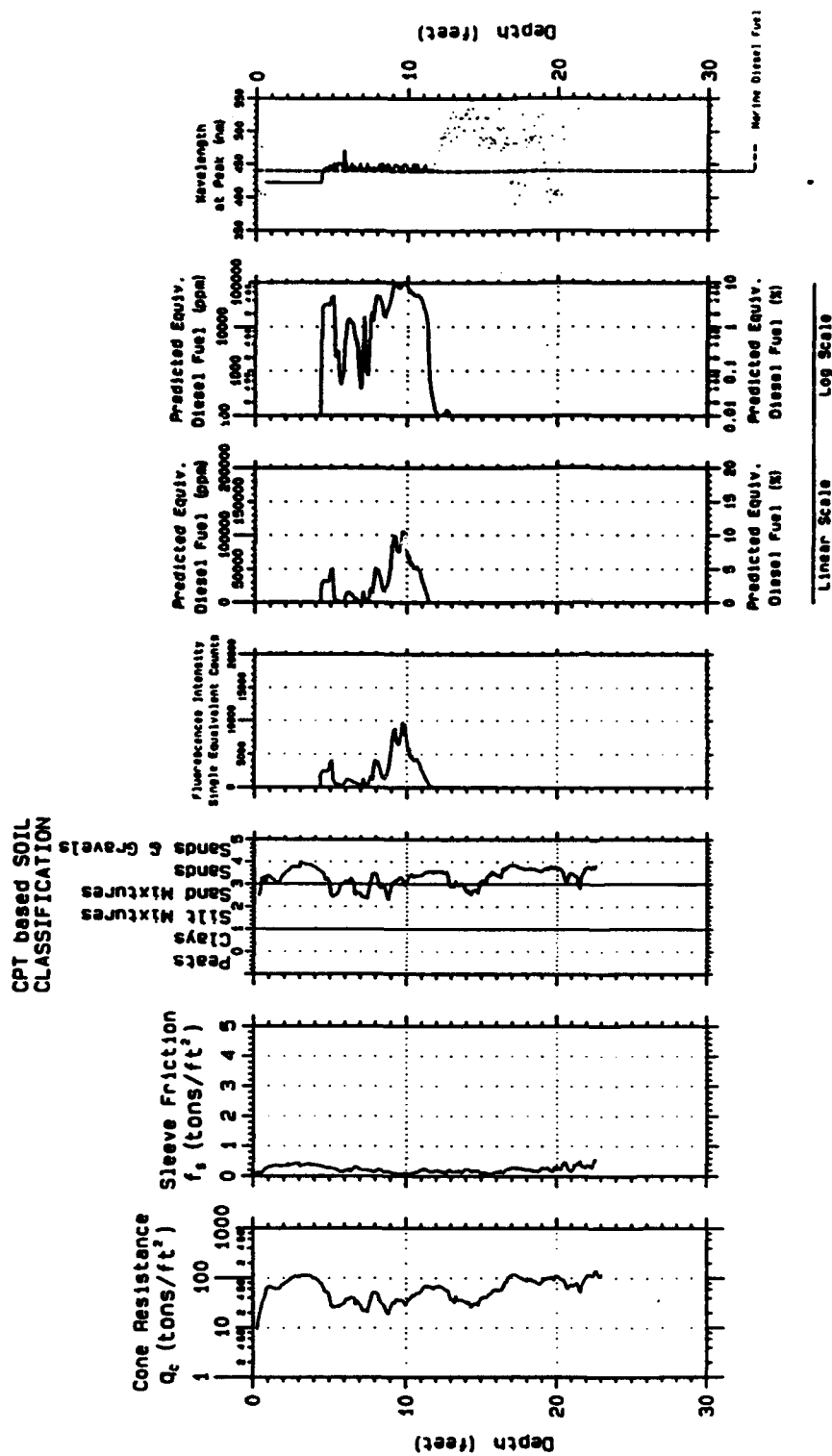


CPT based SOIL  
CLASSIFICATION

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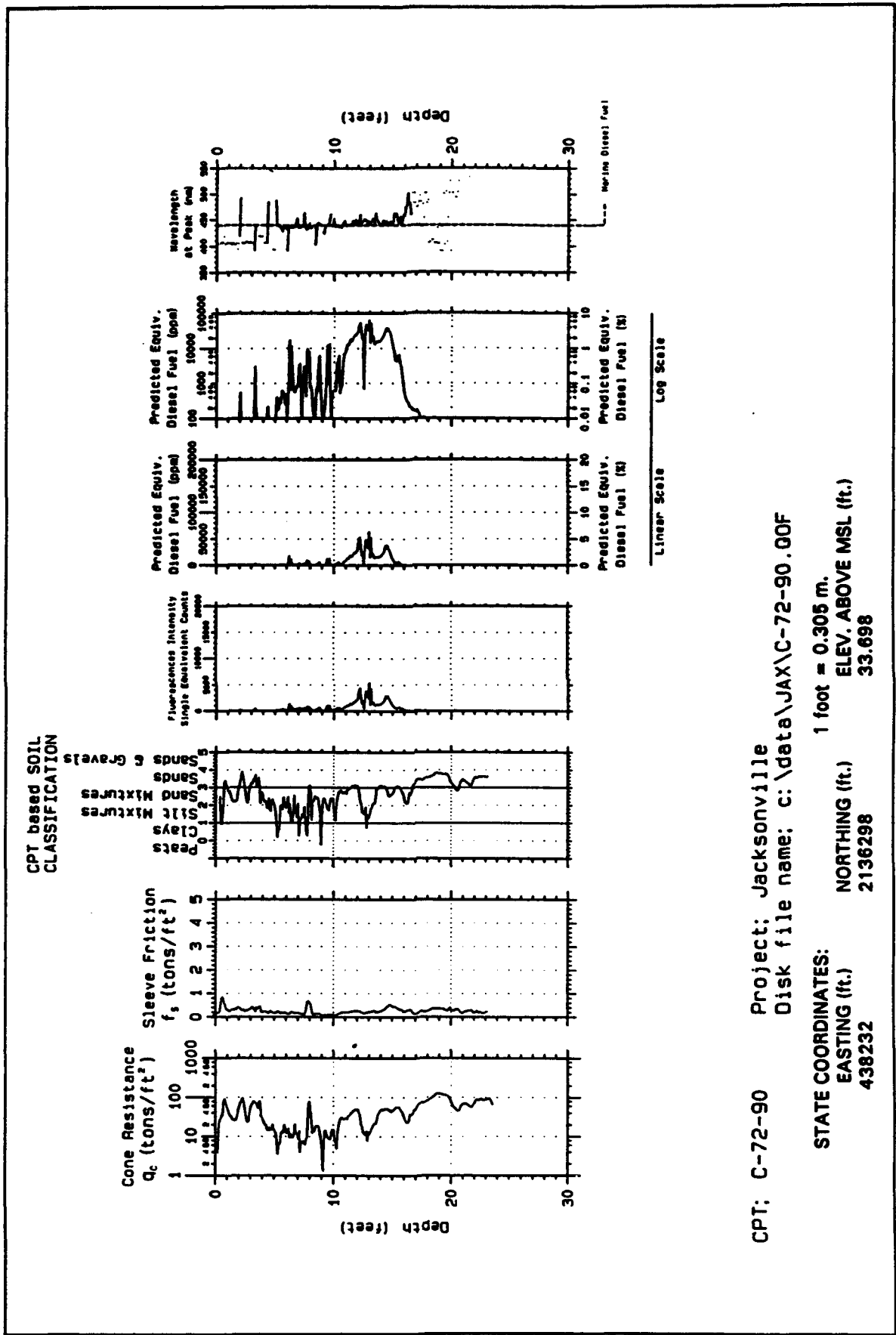
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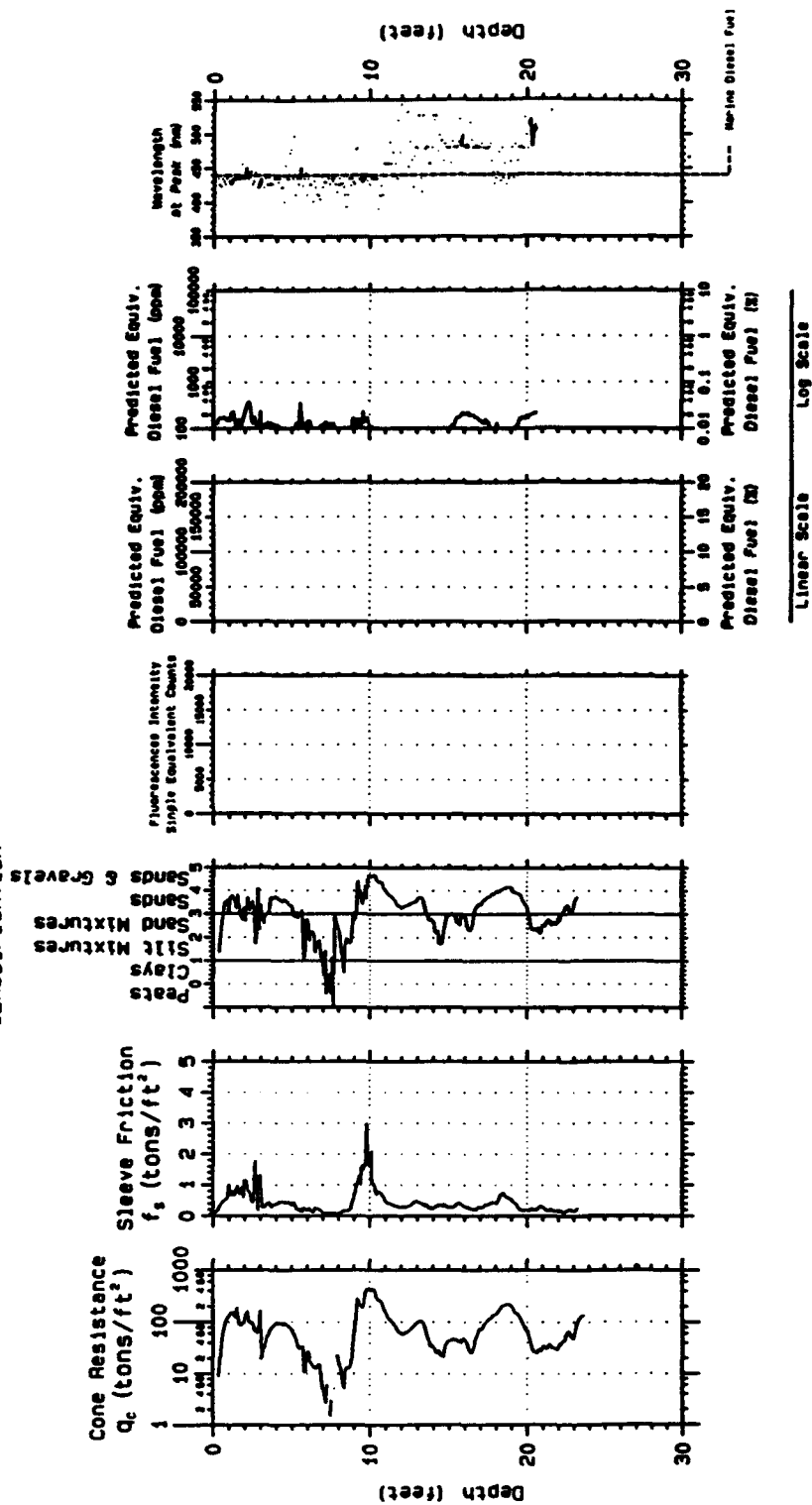




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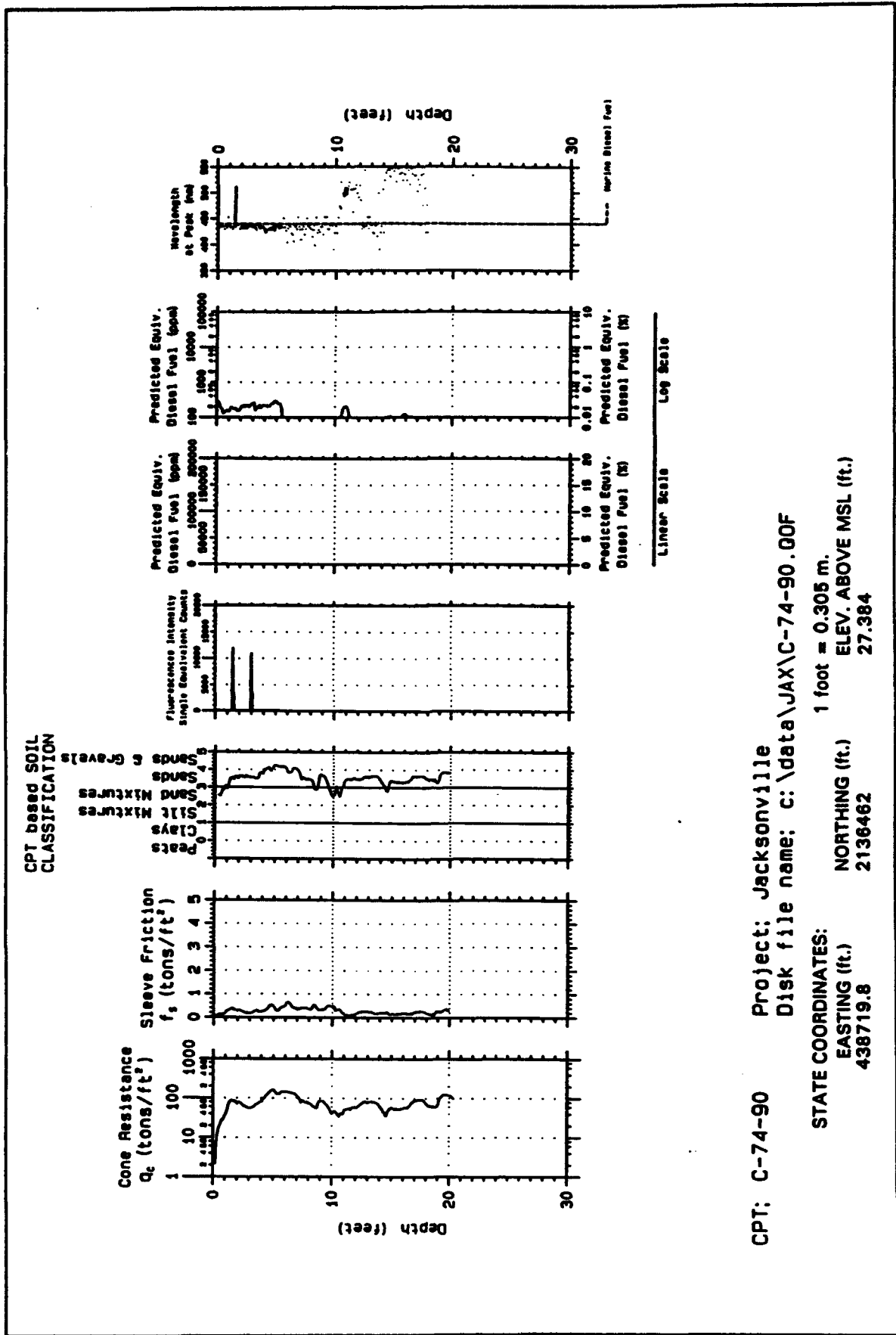


CPT based SOIL  
CLASSIFICATION

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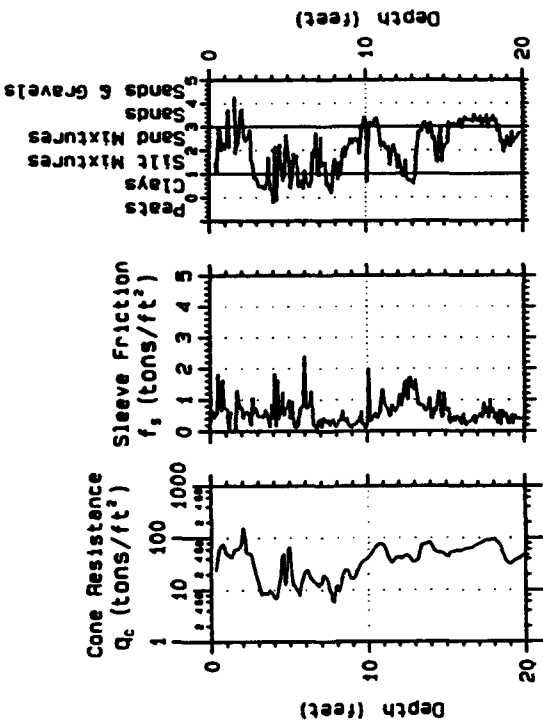


# **Appendix B**

## **Data from the Penetrometer Unit Equipped with a Soil Strength Measuring System and the Electrical Resistivity Sensor**

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CPT based SOIL  
CLASSIFICATION

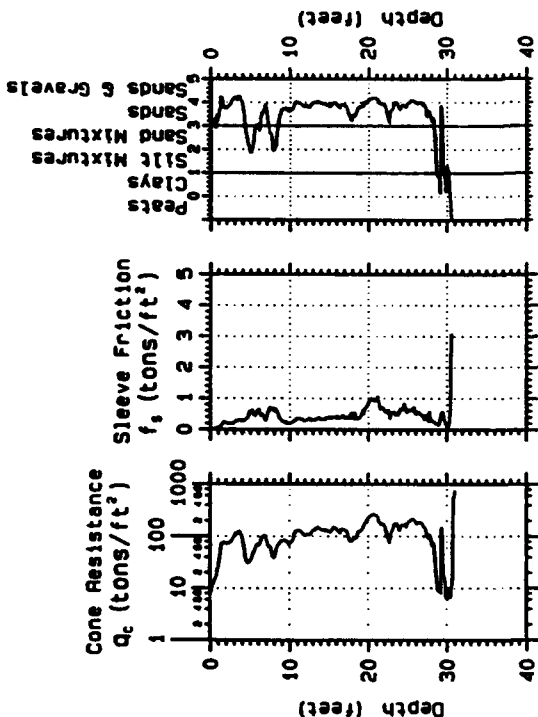


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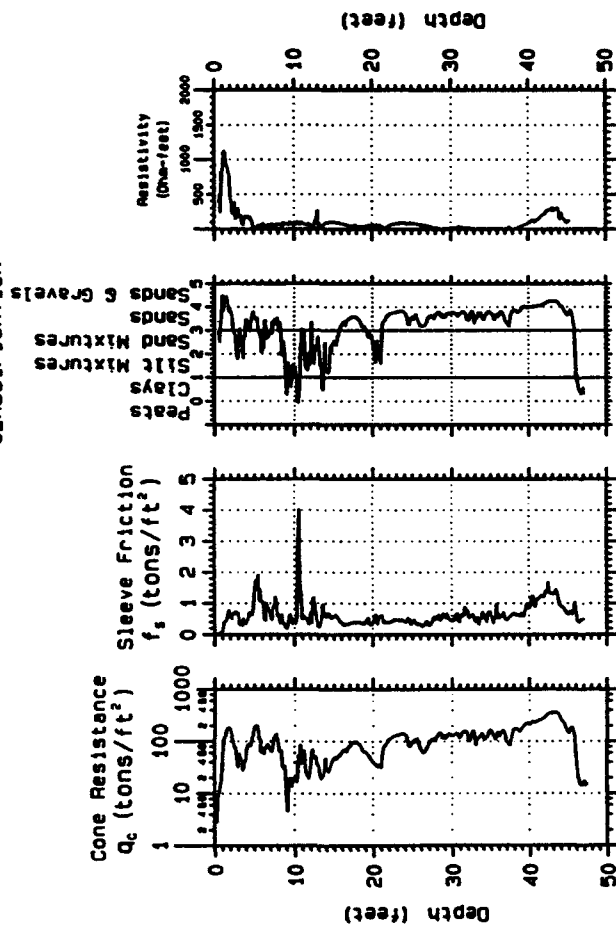
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CPT based SOIL  
CLASSIFICATION



CPT: C-78-90      Project: Jacksonville      1 foot = 0.305 m.  
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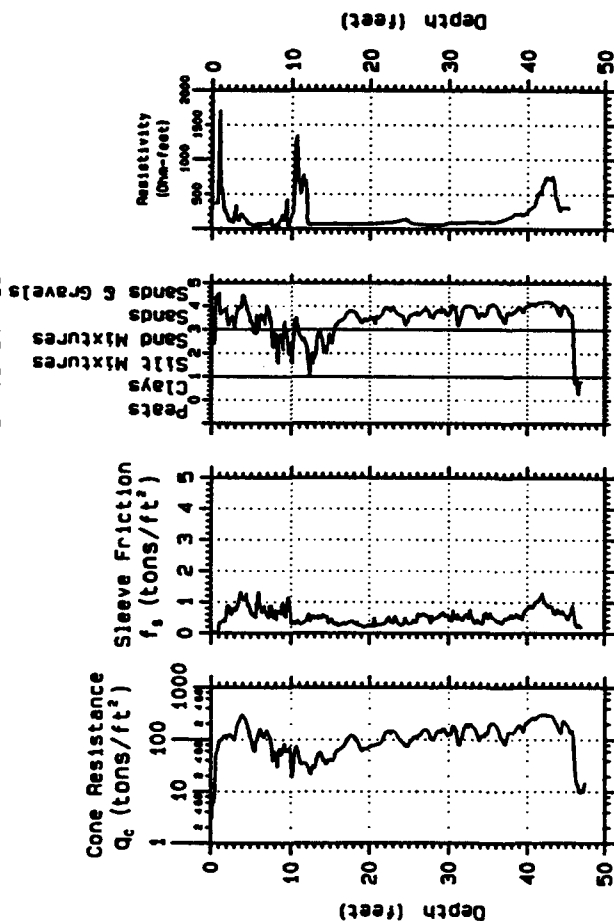
CPT based SOIL  
CLASSIFICATION



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ELEV. ABOVE MSL (ft.)      32.041

CPT based SOIL  
CLASSIFICATION

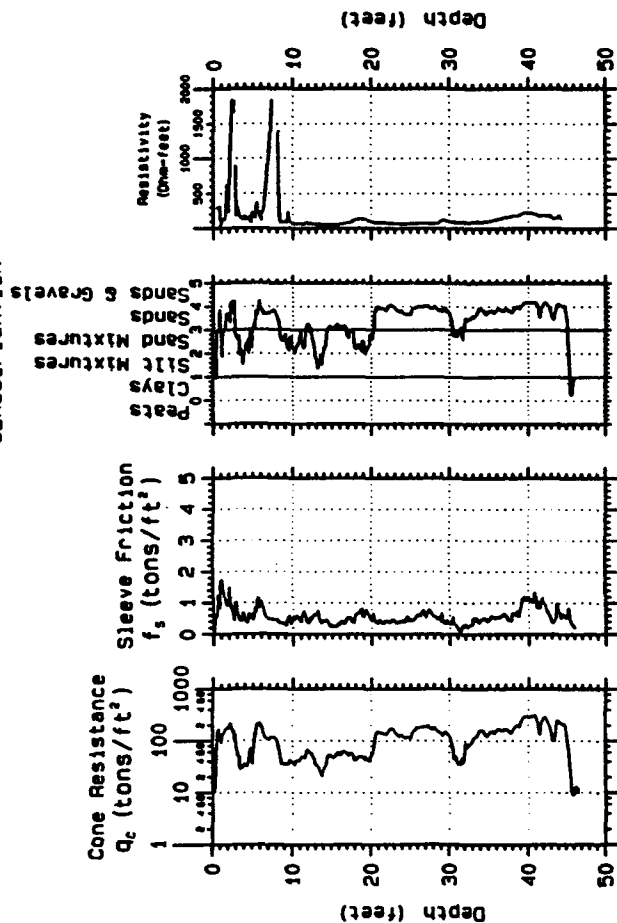


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STATE COORDINATES:      1 foot = 0.305 m.      ELEV. ABOVE MSL (ft.)      32.571

EASTING (ft.)      2135869      NORTHING (ft.)      438181

CPT based SOIL  
CLASSIFICATION

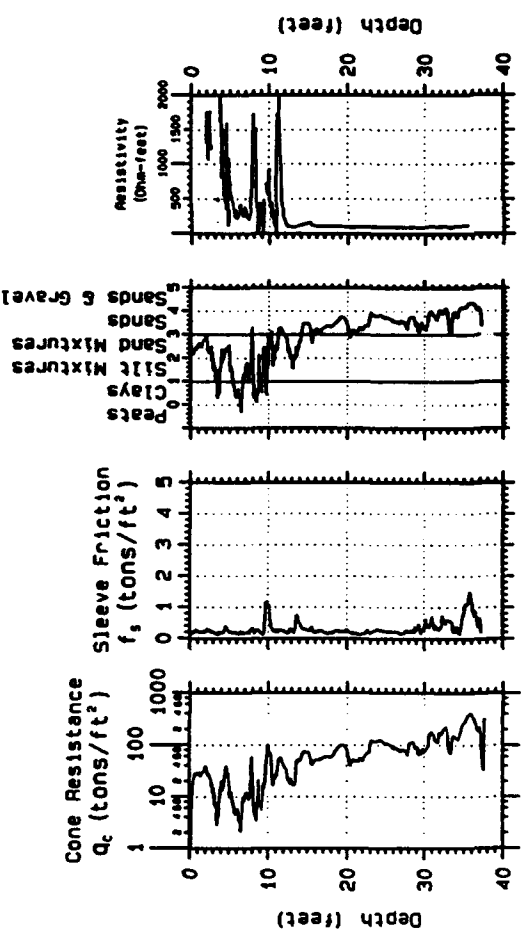


CPT: C-75-90      Project: Jacksonville      Disk file name: c:\data\JAX\C-75-90.ORF

STATE COORDINATES:      1 foot = 0.305 m.      ELEV. ABOVE MSL (ft.)      31.143

EASTING (ft.)      438160      NORTHING (ft.)      2135820

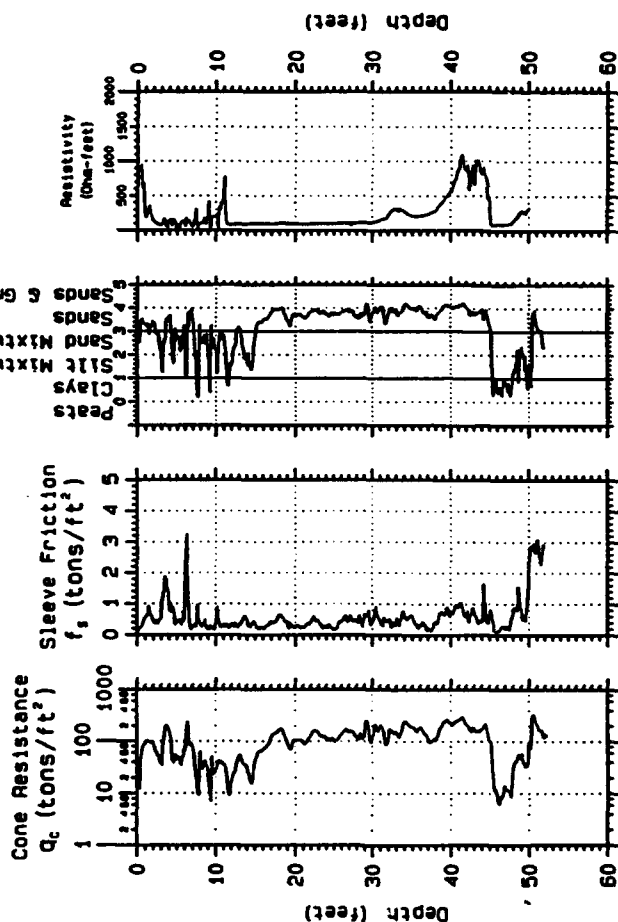
CPT based SOIL CLASSIFICATION



CPT: C-63-90      Project: Jacksonville  
Disk file name: c:\data\JAX\C-63-90.0RF

STATE COORDINATES:      1 foot = 0.305 m.  
EASTING (ft.)      438293.9      NORTHING (ft.)      2136269      ELEV. ABOVE MSL (ft.)      33.688

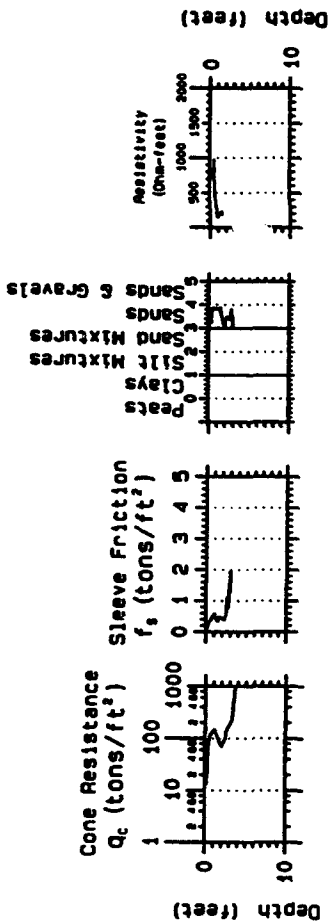
CPT based SOIL  
CLASSIFICATION



CPT: C-64-90      Project: Jacksonville  
Disk file name: c:\data\JAX\C-64-90.GRF

STATE COORDINATES:      1 foot = 0.305 m.  
EASTING (ft.)      438106.1      NORTHING (ft.)      2135890  
ELEV. ABOVE MSL (ft.)      32.126

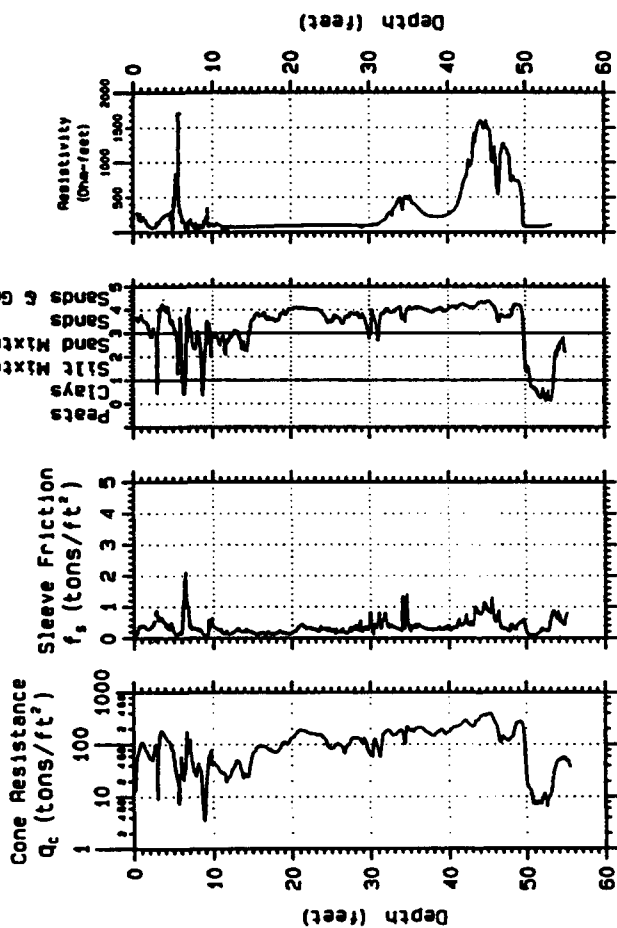
CPT based SOIL  
CLASSIFICATION



CPT: C-65-90      Project: Jacksonville  
 Disk file name: c:\data\JAX\C-65-90.GRF

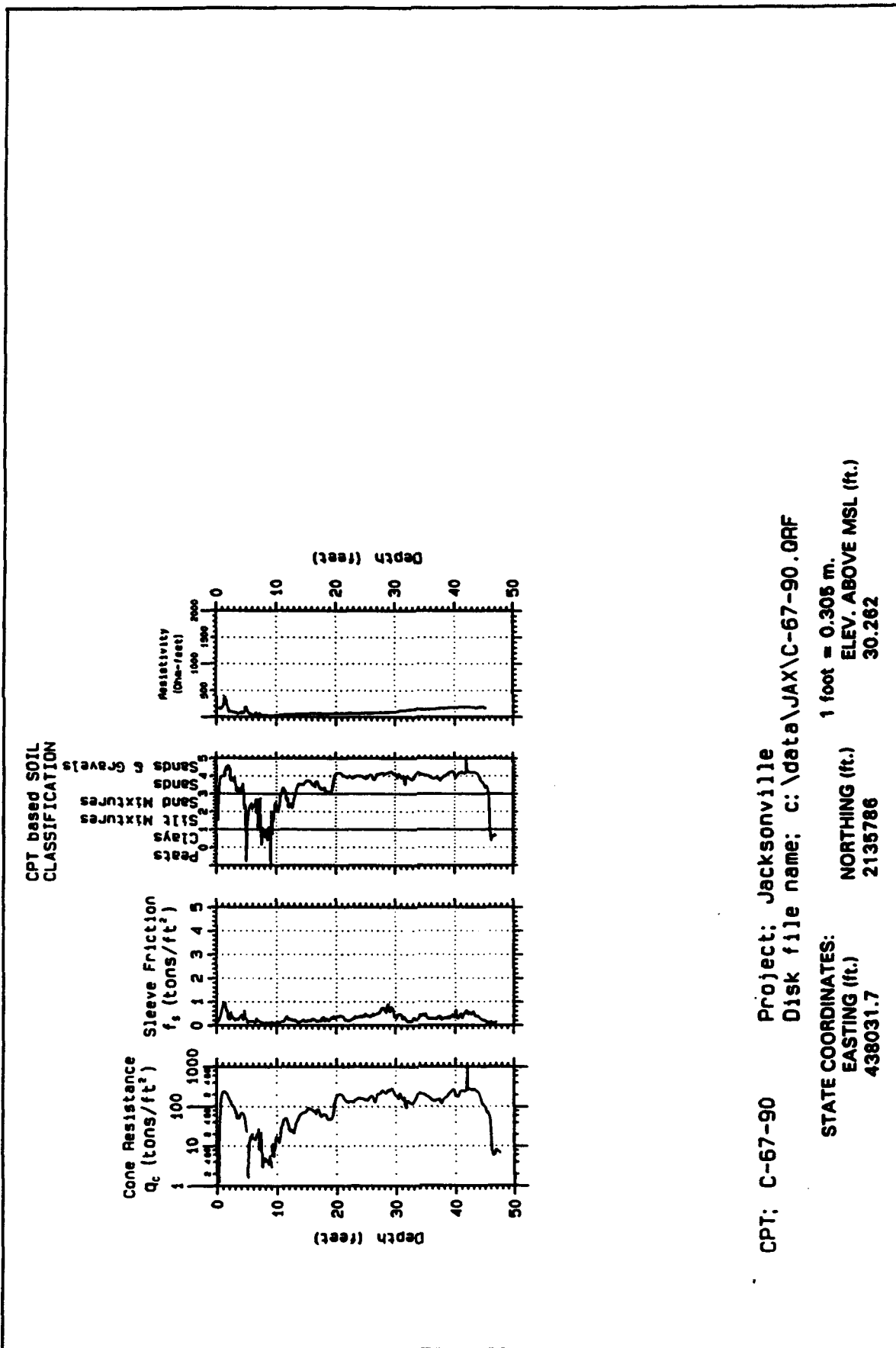
STATE COORDINATES:      1 foot = 0.305 m.  
 EASTING (ft.)      NORTHING (ft.)      ELEV. ABOVE MSL (ft.)  
 438089.9      213588.1      31.573

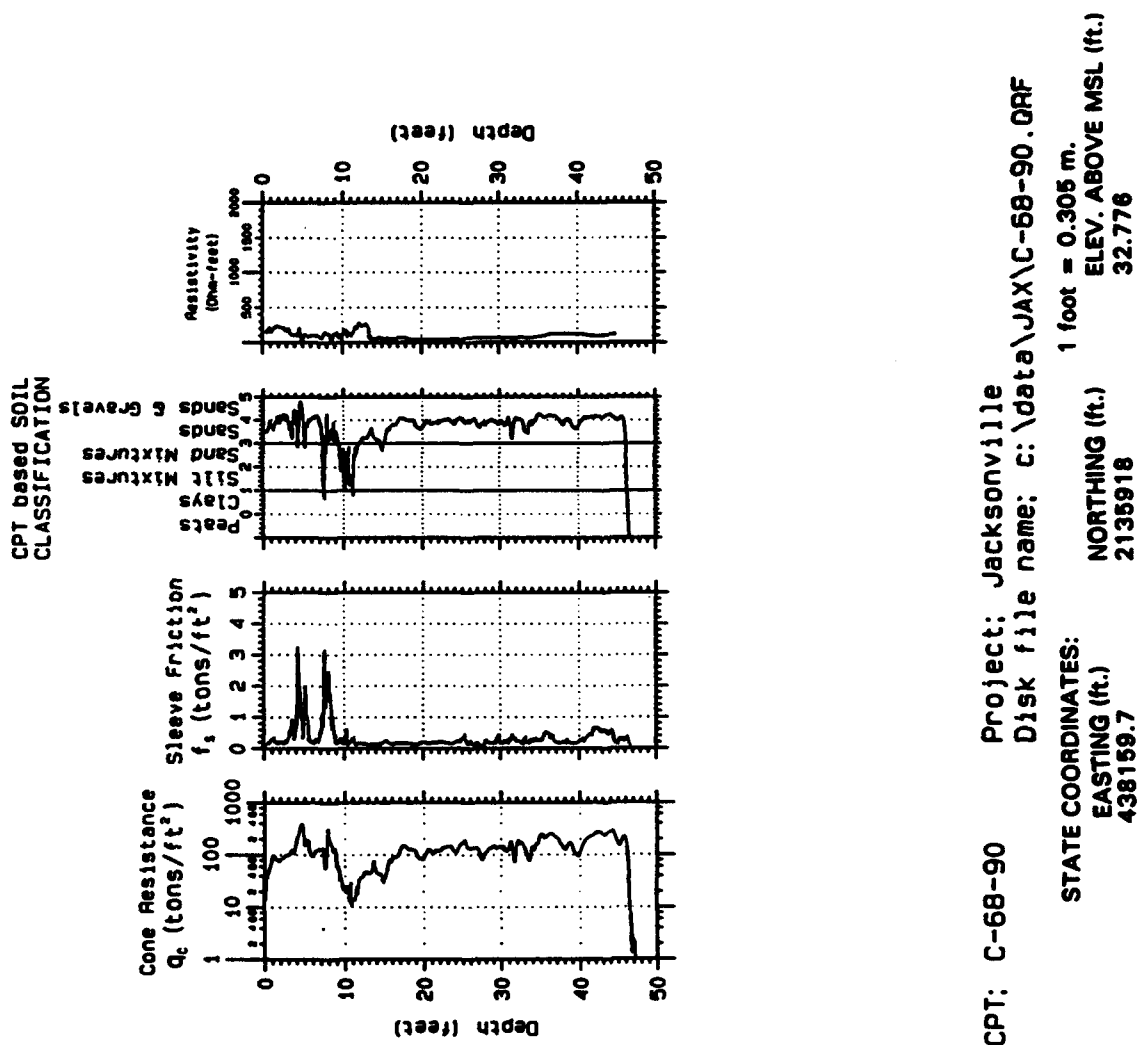
CPT based SOIL  
CLASSIFICATION



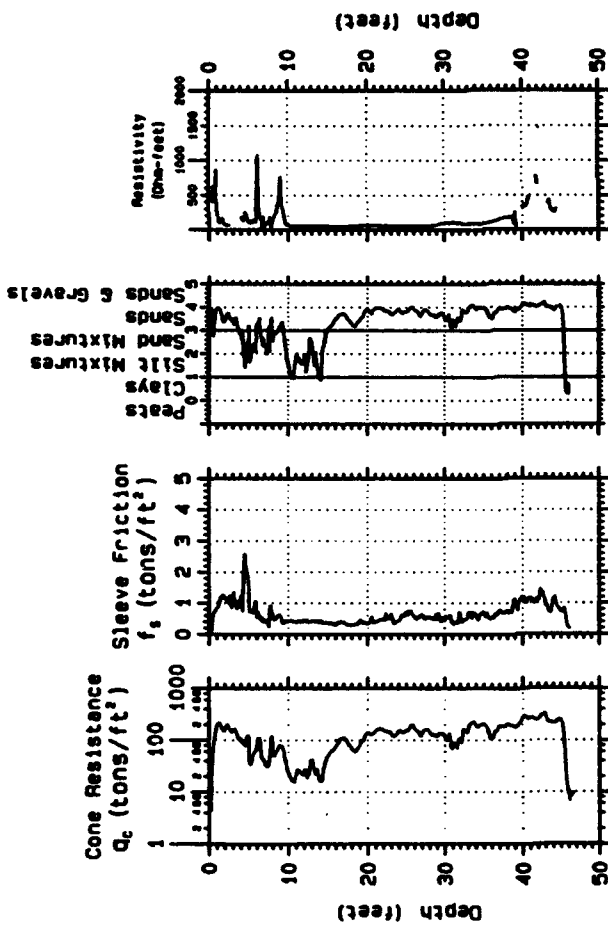
CPT: C-66-90      Project: Jacksonville      Disk file name: c:\data\JAX\C-66-90.QRF

STATE COORDINATES:      1 foot = 0.305 m.  
EASTING (ft.)      2135875      NORTHING (ft.)      ELEV. ABOVE MSL (ft.)  
438079.2      31.776





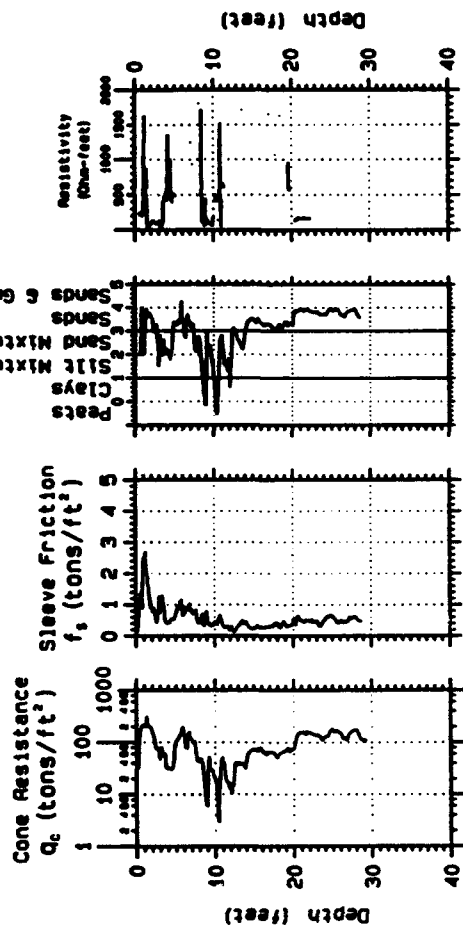
CPT based SOIL  
CLASSIFICATION



CPT: C-69-90      Project: Jacksonville      Disk file name: c:\data\JAX\C-69-90.QRF

STATE COORDINATES:      1 foot = 0.305 m.  
EASTING (ft.)      438129.7      NORTHING (ft.)      2135862  
ELEV. ABOVE MSL (ft.)      31.592

CPT based SOIL CLASSIFICATION



CPT: C-70-90 Project: Jacksonville  
Disk file name: c:\data\JAX\C-70-90.QRF

STATE COORDINATES: 1 foot = 0.305 m.  
EASTING (ft.) 438154.1 ELEV. ABOVE MSL (ft.) 31.051  
NORTHING (ft.) 2135811

# **Appendix C**

## **Data from the Chemical Analysis of Soil and Water Samples Collected at the Jacksonville Naval Air Station**

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JOB FILE: 07044

DATE: 14 JAN 91

\*\*\*\*\* ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET (PAGE 1 OF 1)\*\*\*\*\*

Q DESCRIPTION: JACKSONVILLE HAS - GL  
 .REN. PRESERVATIVE:

JOB NUMBER: R00G42501170001  
 TYPE OF SAMPLE: SEDIMENT

RECEIPT DATE: 16 AUG 90  
 EST. COMP. DATE: 14 SEP 90

COLUMN..... 1  
 ANALYTE..... 100  
 MG/KG..... O&G

SAMP #	DESCRIPTION	CONC	XREC	DUPL	OID	ROW
07044	TAKEN IN DITCH SIDE near C-30-90 8-14-90	22570		20600	05990248	1
07045	TAKEN IN DITCH BOTTOM near C-30-90 8-14-90	56600		05990248		2
07046	9.5 DEEP near C-62-90 8-14-90 Depth is top of 18" sample	62500		05990248		3
07047	10.5 DEPTH near C-76-90 8-14-90 Depth is top of 18" sample	374		05990248		4
07048	11 DEPTH near C-30-90 8-14-90 Depth is top of 18" sample	175		05990248		5
BL#01	METHOD BLANK	<5.0	102.6		05990248	6

O&G Oil & Grease

JOB FILE: 07042

DATE: 14 JAN 91

\*\*\*\*\* ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET (PAGE 1 OF 7)\*\*\*\*\*

DESCRIPTION: JACKSONVILLE NAS - GL

JOB NUMBER: R00G425E1170001

RECEIPT DATE: 16 AUG 90

PRESERVATIVE:

TYPE OF SAMPLE: SEDIMENT

EST. COMP. DATE: 31 AUG 90

COLUMN.....	1	2	3	4	5	6
ANALYTE.....	183	184	185	186	187	188
MG/KG.....	CLMETH	BrMETH	VNLCL	CLTMA	MECL	11DCLETE

SAMP #	DESCRIPTION								ROW
07042	TAKEN AT 1'	CONC	<0.14	<0.14	<0.14	<0.14	0.79	<0.028	1
	near C-77-90	XREC							
	8-13-90	DUPL							
	Depth of top of	OID	08930232	08930232	08930232	08930232	08930232	08930232	
	.18" sample								
07043	TAKEN AT 45'	CONC	<0.012	<0.012	<0.012	<0.012	0.17	<0.0061	2
	DEPTH	XREC							
	6" east of	DUPL							
	C-66-90	OID	08930232	08930232	08930232	08930232	08930232	08930232	
	8-13-90								
BL001	METHOD BLANK	CONC	<0.010	<0.010	<0.010	<0.010	0.0036 J #1	<0.005	3
		XREC							
		DUPL							
		OID	08930232	08930232	08930232	08930232	08930232	08930232	

CLMETH Chloromethane  
VNLCL Vinyl Chloride  
MECL Methylene Chloride

BrMETH Bromomethane  
CLTMA Chloroethane  
11DCLETE 1,1-Dichloroethene

## FOOTNOTES:

#1 J indicates value below statistical quantitation limits.

JOB FILE: 07042

DATE: 14 JAN 91

\*\*\*\*\* ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET (PAGE 2 OF 7)\*\*\*\*\*

JB DESCRIPTION: JACKSONVILLE HAS - GL  
 CNEM. PRESERVATIVE:

JOB NUMBER: R00G425E1170001  
 TYPE OF SAMPLE: SEDIMENT

RECEIPT DATE: 16 AUG 90  
 EST. COMP. DATE: 31 AUG 90

COLUMN.....	7	8	9	10	11	12
ANALYTE.....	189	190	191	192	193	194
MG/KG.....	11DCIETA	t-DCIETE	c-DCIETE	CNCL3	12DCIETA	111TCA

SAMP #	DESCRIPTION	CONC	0.0048 J #1	<0.028	<0.028	<0.028	<0.028	<0.028	ROW
07042	TAKEN AT 1'								1
	DEPTH	ZREC							
	near C-77-90	DUPL							
	8-13-90	OID	08930232	08930232	08930232	08930232	08930232	08930232	
	Depth of top of 18" sample								
07043	TAKEN AT 45'	CONC	<0.0061	<0.0061	<0.0061	0.0022 J #1	<0.0061	<0.0061	2
	DEPTH	ZREC							
	6" east of C-66-90	DUPL							
	8-13-90	OID	08930232	08930232	08930232	08930232	08930232	08930232	
BL#01	METHOD BLANK	CONC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	3
		ZREC							
		DUPL							
		OID	08930232	08930232	08930232	08930232	08930232	08930232	

11DCIETA 1,1-Dichloroethane  
 c-DCIETE cis-1,2-Dichloroethane  
 12DCIETA 1,2-Dichloroethane

t-DCIETE Trans-1,2-Dichloroethane  
 CNCL3 Chloroform  
 111TCA 1,1,1-Trichloroethane

## FOOTNOTES:

#1 J indicates value below statistical quantitation limits.

JOB FILE: 07042

DATE: 14 JAN 91

\*\*\*\*\* ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET (PAGE 3 OF 7)\*\*\*\*\*

JO DESCRIPTION: JACKSONVILLE HAS - GL  
 CHEM. PRESERVATIVE:

JOB NUMBER: RDOG425E1170001  
 TYPE OF SAMPLE: SEDIMENT

RECEIPT DATE: 16 AUG 90  
 EST. COMP. DATE: 31 AUG 90

COLUMN.....	13	14	15	16	17	18
ANALYTE.....	195	196	197	198	199	200
MG/KG.....	CCL4	BrDCINE	12DC1PR	t13C1PRE	TCE	DBrCINE

SAMP #	DESCRIPTION	CONC	0.0046 J #1	<0.028	<0.028	<0.028	<0.028	ROW
07042	TAKEN AT 1'	CONC <0.028	0.0046 J #1	<0.028	<0.028	<0.028	<0.028	1
	DEPTH	3REC						
	near C-77-90	DUP1						
	8-13-90	OID 08930232	08930232	08930232	08930232	08930232	08930232	
	Depth of top of							
	18" sample							
07043	TAKEN AT 45'	CONC <0.0061	0.012 J #1	<0.0061	<0.0061	<0.0061	<0.0061	2
	DEPTH	3REC						
	6" east of	DUP1						
	C-66-90	OID 08930232	08930232	08930232	08930232	08930232	08930232	
	8-13-90							
BL#01	METHOD BLANK	CONC <0.005	<0.005	<0.005	<0.005	<0.005	<0.005	3
		3REC						
		DUP1						
		OID 08930232	08930232	08930232	08930232	08930232	08930232	

CCL4 Carbon Tetrachloride  
 12DC1PR 1,2-Dichloropropane  
 TCE Trichloroethene

BrDCINE Bromodichloromethane  
 t13C1PRE Trans-1,3-Dichloropropane  
 DBrCINE Dibromochloromethane

## FOOTNOTES:

#1 J indicates value below statistical quantitation limits.

JOB FILE: 07042

DATE: 14 JAN 91

\*\*\*\*\* ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET (PAGE 4 OF 7)\*\*\*\*\*

JOB DESCRIPTION: JACKSONVILLE NAS - GL  
CHEM. PRESERVATIVE:JOB NUMBER: R00G425E1170001  
TYPE OF SAMPLE: SEDIMENTRECEIPT DATE: 16 AUG 90  
EST. COMP. DATE: 31 AUG 90

COLUMN.....	19	20	21	22	23	24
ANALYTE.....	201	202	203	205	206	207
MG/KG.....	c13CIPRE	112TCA	BENZENE	CHBr3	1122TCIA	TECLETE

SAMP #	DESCRIPTION								ROW
07042	TAKEN AT 1'	CONC	<0.028	<0.028	0.018 J #1	<0.028	0.15	<0.028	1
	DEPTH	%REC							
	near C-77-90	DUPL							
	8-13-90	OID	08930232	08930232	08930232	08930232	08930232	08930232	
	Depth of top of								
	18" sample								
07043	TAKEN AT 45'	CONC	<0.0061	<0.0061	<0.0061	<0.0061	<0.0061	<0.0061	2
	DEPTH	%REC							
	6" east of	DUPL							
	C-66-90	OID	08930232	08930232	08930232	08930232	08930232	08930232	
	8-13-90								
BLR01	METHOD BLANK	CONC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	3
		%REC							
		DUPL							
		OID	08930232	08930232	08930232	08930232	08930232	08930232	

c13CIPRE Cis-1,3-Dichloropropene  
 BENZENE Benzene  
 1122TCIA 1,1,2,2-Tetrachloroethane

112TCA 1,1,2-Trichloroethane  
 CHBr3 Bromoform  
 TECLETE Tetrachloroethene

## FOOTNOTES: -

#1 J indicates value below statistical quantitation limits.

JOB FILE: 07042

DATE: 14 JAN 91

\*\*\*\*\* ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET (PAGE 5 OF 7)\*\*\*\*\*

J DESCRIPTION: JACKSONVILLE HAS - GL  
CHEN. PRESERVATIVE:JOB NUMBER: RDGG425E1170001  
TYPE OF SAMPLE: SEDIMENTRECEIPT DATE: 16 AUG 90  
EST. COMP. DATE: 31 AUG 90

COLUMN.....	25	26	27	28	29	30		
ANALYTE.....	208	209	210	213	214	215		
MG/KG.....	TOLUENE	CIBEN	ETBEN	ACETONE	BUTANO	CS2		
SAMP #	DESCRIPTION						ROW	
07042	TAKEN AT 1'	CONC 0.091	3.8	0.94	0.20 J #1	<0.56	<0.028	1
	DEPTH	XREC						
	near C-77-90	DUPL						
	8-13-90	Q1D 08930232	08930232	08930232	08930232	08930232	08930232	
	Depth of top of							
	18" sample							
07043	TAKEN AT 45'	CONC <0.0061	<0.0061	<0.0061	0.027 J #1	<0.12	<0.0061	2
	DEPTH	XREC						
	6" east of	DUPL						
	C-66-90	Q1D 08930232	08930232	08930232	08930232	08930232	08930232	
	8-13-90							
BL#01	METHOD BLANK	CONC <0.005	<0.005	<0.005	0.014 J #1	<0.10	<0.005	3
		XREC						
		DUPL						
		Q1D 08930232	08930232	08930232	08930232	08930232	08930232	

TOLUENE Toluene  
ETBEN Ethylbenzene  
BUTANO 2-ButanoneCIBEN Chlorobenzene  
ACETONE Acetone  
CS2 Carbondisulfide

## FOOTNOTES:

#1 J indicates value below statistical quantitation limits.

JOB FILE: 07042

DATE: 14 JAN 91

\*\*\*\*\* ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET (PAGE 6 OF 7)\*\*\*\*\*

JOB DESCRIPTION: JACKSONVILLE HAS - GL  
CHEM. PRESERVATIVE:JOB NUMBER: RD06425E1170001  
TYPE OF SAMPLE: SEDIMENTRECEIPT DATE: 16 AUG 90  
EST. COMP. DATE: 31 AUG 90

COLUMN.....	31	32	33	34	35	36		
ANALYTE.....	216	217	218	219	220	221		
MG/KG.....	2HEXANO	4Me2PE	STYRENE	VMACETA	T-XYLENE	12DCL-E-S		
SAMP #	DESCRIPTION							ROW
07042	TAKEN AT 1'	CONC <0.28	<0.28	<0.028	<0.28	1.1	115%	1
	DEPTH	XREC						
	near C-77-90	DUPL						
	8-13-90	OID 08930232	08930232	08930232	08930232	08930232	08930232	
	Depth of top of							
	18" sample							
07043	TAKEN AT 45'	CONC <0.061	<0.061	<0.0061	<0.061	<0.0061	113%	2
	DEPTH	XREC						
	6" east of	DUPL						
	C-66-90	OID 08930232	08930232	08930232	08930232	08930232	08930232	
	8-13-90							
BL#01	METHOD BLANK	CONC <0.050	<0.050	<0.005	<0.050	<0.005	104%	3
		XREC						
		DUPL						
		OID 08930232	08930232	08930232	08930232	08930232	08930232	

2HEXANO 2-Hexanone  
STYRENE Styrene  
T-XYLENE T-Xylene4Me2PE 4-Methyl-2-Pentanone  
VMACETA Vinyl Acetate  
12DCL-E-S 1,2-Dichloroethane-d4(Surrogate (70-121))

JOB FILE: 07042

DATE: 14 JAN 91

\*\*\*\*\* ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET (PAGE 7 OF 7)\*\*\*\*\*

JOB DESCRIPTION: JACKSONVILLE HAS - GL  
CHEM. PRESERVATIVE:

JOB NUMBER: RDOG425E1170001  
TYPE OF SAMPLE: SEDIMENT

RECEIPT DATE: 16 AUG 90  
EST. COMP. DATE: 31 AUG 90

COLUMN..... 37                      38  
ANALYTE..... 222                    223  
MG/KG..... TOL-dB-S      4BrFB-S

SAMP #	DESCRIPTION	CONC	%REC	DUPL	OID	ROW
07042	TAKEN AT 1'	89.3%	102%			1
	DEPTH					
	near C-77-90					
	8-13-90					
	Depth of top of					
	18" sample					
07043	TAKEN AT 45'	98.7%	97.0%			2
	DEPTH					
	6" east of					
	C-66-90					
	8-13-90					
BL#01	METHOD BLANK	97.2%	97.0%			3

TOL-dB-S Toluene-d8(Surrogate (81-117))

4BrFB-S 4-Bromofluorobenzene(Surrogate (74-121))

JOB FILE: 07041

DATE: 14 JAN 91

\*\*\*\*\* ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET (PAGE 1 OF 7)\*\*\*\*\*

DESCRIPTION: JACKSONVILLE NAS - GL  
 PRESERVATIVE:

JOB NUMBER: RDOG425E1170001  
 TYPE OF SAMPLE: Water

RECEIPT DATE: 16 AUG 90  
 EST. COMP. DATE: 31 AUG 90

COLUMN.....	1	2	3	4	5	6
ANALYTE.....	183	184	185	186	187	188
PPM.....	CIETH	BrMETH	VNLCL	CIETHA	MECL	11DCIETE

SAMP #	DESCRIPTION							ROW	
07041	43.5 DEPTH	CONC	<0.010	<0.010	<0.010	<0.010	<0.005	<0.005	1
	8/13/90	SDREC							
	near C-76-90	DUP1							
	Depth is screen of	Q10	08930232	08930223	08930232	08930232	08930232	08930232	
	Hydropunch								
BL#01	METHOD BLANK	CONC	<0.010	<0.010	<0.010	<0.010	0.0036 J #1	<0.005	2
		SDREC							
		DUP1							
		Q10	08930232	08930232	08930232	08930232	08930232	08930232	

CIETH	Chloromethane	BrMETH	Bromomethane
VNLCL	Vinyl Chloride	CIETHA	Chloroethane
MECL	Methylene Chloride	11DCIETE	1,1-Dichloroethane

## FOOTNOTES:

#1 J indicated value below statistical quantitation limits.

JOB FILE: 07041

DATE: 14 JAN 91

\*\*\*\*\* ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET (PAGE 2 OF 7)\*\*\*\*\*

JOB DESCRIPTION: JACKSONVILLE HAS - GL  
CHEM. PRESERVATIVE:

JOB NUMBER: RD06425E1170001  
TYPE OF SAMPLE: Water

RECEIPT DATE: 16 AUG 90  
EST. COMP. DATE: 31 AUG 90

COLUMN.....	7	8	9	10	11	12
ANALYTE.....	189	190	191	192	193	194
PPM.....	11DCIETA	t-DCIETE	c-DCIETE	CMCL3	12DCIETA	111TCA

SAMP #	DESCRIPTION	CONC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	ROW
07041	43.5 DEPTH	CONC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	1
	8/13/90	2REC							
	<i>near C-76-90</i>	DUPL							
	<i>Depth is screen of</i>	OID	08930232	08930232	08930232	08930232	08930232	08930232	
	<i>Hydropunch</i>								
BL#01	METHOD BLANK	CONC	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	2
		2REC							
		DUPL							
		OID	08930232	08930232	08930232	08930232	08930232	08930232	

11DCIETA 1,1-Dichloroethane  
c-DCIETE cis-1,2-Dichloroethane  
12DCIETA 1,2-Dichloroethane

t-DCIETE Trans-1,2-Dichloroethane  
CMCL3 Chloroform  
111TCA 1,1,1-Trichloroethane

JOB FILE: 07041

DATE: 14 JAN 91

\*\*\*\*\* ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET (PAGE 3 OF 7)\*\*\*\*\*

J DESCRIPTION: JACKSONVILLE HAS - GL  
CHEM. PRESERVATIVE:

JOB NUMBER: BDOG425E1170001  
TYPE OF SAMPLE: Water

RECEIPT DATE: 16 AUG 90  
EST. COMP. DATE: 31 AUG 90

COLUMN.....	13	14	15	16	17	18
ANALYTE.....	195	196	197	198	199	200
PPM.....	CCL4	BrDCINE	12DCIPR	t13CIPRE	TCE	DBrCINE

SAMP #	DESCRIPTION							ROW
07041	43.5 DEPTH	CONC	<0.005	<0.005	<0.005	<0.005	<0.005	1
	8/13/90	%REC						
	near C-76-90	DUPL						
	Depth is screen of	OID	08930232	08930232	08930232	08930232	08930232	
	Hydropunch							
BL#01	METHOD BLANK	CONC	<0.005	<0.005	<0.005	<0.005	<0.005	2
		%REC						
		DUPL						
		OID	08930232	08930232	08930232	08930232	08930232	

CCL4 Carbon Tetrachloride  
12DCIPR 1,2-Dichloropropane  
TCE Trichloroethene

BrDCINE Bromodichloromethane  
t13CIPRE Trans-1,3-Dichloropropene  
DBrCINE Dibromochloromethane

JOB FILE: 07041

DATE: 14 JAN 91

\*\*\*\*\* ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET (PAGE 4 OF 7) \*\*\*\*\*

LOW DESCRIPTION: JACKSONVILLE HAS - GL  
CHEM. PRESERVATIVE:

JOB NUMBER: RD06425E1170001  
TYPE OF SAMPLE: Water

RECEIPT DATE: 16 AUG 90  
EST. COMP. DATE: 31 AUG 90

COLUMN.....	19	20	21	22	23	24
ANALYTE.....	201	202	203	205	206	207
PPM.....	c13C1PRE	112TCA	BENZENE	CHBr3	1122TCA	TEC1ETE

SAMP #	DESCRIPTION							ROW
07041	43.5 DEPTH	CONC	<0.005	<0.005	<0.005	<0.005	<0.005	1
	8/13/90	XREC						
	near C-76-90	DUPL						
	Depth is screen of	OID	00930232	00930232	00930232	00930232	00930232	
	Hydropunch							
BL001	METHOD BLANK	CONC	<0.005	<0.005	<0.005	<0.005	<0.005	2
		XREC						
		DUPL						
		OID	00930232	00930232	00930232	00930232	00930232	

c13C1PRE	Cis-1,3-Dichloropropene	112TCA	1,1,2-Trichloroethane
BENZENE	Benzene	CHBr3	Bromoform
1122TCA	1,1,2,2-Tetrachloroethane	TEC1ETE	Tetrachloroethane

JOB FILE: 07041

DATE: 14 JAN 91

\*\*\*\*\* ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET (PAGE 5 OF 7)\*\*\*\*\*

JOB DESCRIPTION: JACKSONVILLE HAS - GL  
CHEM. PRESERVATIVE:

JOB NUMBER: R00G425E1170001  
TYPE OF SAMPLE: Water

RECEIPT DATE: 16 AUG 90  
EST. COMP. DATE: 31 AUG 90

COLUMN.....	25	26	27	28	29	30
ANALYTE.....	208	209	210	213	214	215
PPM.....	TOLUENE	CIBEN	ETBEN	ACETONE	BUTANO	CS2

SAMP #	DESCRIPTION										ROW				
07041	43.5 DEPTH	CONC	<0.005		0.0018 J #1		<0.005		0.005 J #1		<0.10		<0.005		1
	8/13/90	XREC													
	near C-76-90	DUPL													
	Depth is screen of	OID	00930232		00930232		00930232		00930232		00930232		00930232		
	Hydropunch														
BL001	METHOD BLANK	CONC	<0.005		<0.005		<0.005		0.014 J #1		<0.10		<0.005		2
		XREC													
		DUPL													
		OID	00930232		00930232		00930232		00930232		00930232		00930232		

TOLUENE Toluene  
ETBEN Ethylbenzene  
BUTANO 2-Butanone

CIBEN Chlorobenzene  
ACETONE Acetone  
CS2 Carbendisulfide

NOTES:

#1 J indicated value below statistical quantitation limits.

JOB FILE: 07041

DATE: 14 JAN 91

\*\*\*\*\* ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET (PAGE 6 OF 7)\*\*\*\*\*

AS DESCRIPTION: JACKSONVILLE HAS - GL  
CHEM. PRESERVATIVE:

JOB NUMBER: BD06425E1170001  
TYPE OF SAMPLE: Water

RECEIPT DATE: 16 AUG 90  
EST. COMP. DATE: 31 AUG 90

COLUMN.....	31	32	33	34	35	36
ANALYTE.....	216	217	218	219	220	221
PPM.....	2HEXANO	4Me2PE	STYRENE	VMACETA	T-XYLENE	12DCIE-S

SAMP #	DESCRIPTION	CONC	<0.050	<0.050	<0.005	<0.050	<0.005	106%	ROW
07041	43.5 DEPTH	CONC	<0.050	<0.050	<0.005	<0.050	<0.005	106%	1
	8/13/90	XREC							
	near C-76-90	DUP1							
	Depth is screen of	O10	00930232	00930232	00930232	00930232	00930232	00930232	
	Hydropunch								
BL001	METHOD BLANK	CONC	<0.050	<0.050	<0.005	<0.050	<0.005	104%	2
		XREC							
		DUP1							
		O10	00930232	00930232	00930232	00930232	00930232	00930232	

2HEXANO 2-Hexanone

STYRENE Styrene

T-XYLENE T-Xylene

4Me2PE 4-Methyl-2-Pentanone

VMACETA Vinyl Acetate

12DCIE-S 1,2-Dichloroethane-d4(Surrogate (76-114))

JOB FILE: 07041

DATE: 14 JAN 91

\*\*\*\*\* ANALYTICAL LABORATORY GROUP - DATA REPORTING SHEET (PAGE 7 OF 7)\*\*\*\*\*

JOB DESCRIPTION: JACKSONVILLE HAS - GL  
CHEM. PRESERVATIVE:

JOB NUMBER: R00G425E1170001  
TYPE OF SAMPLE: Water

RECEIPT DATE: 16 AUG 90  
EST. COMP. DATE: 31 AUG 90

COLUMN..... 37                      38  
ANALYTE..... 222                    223  
PPM..... TOL-dB-S                4BrFB-S

SAMP #	DESCRIPTION	CONC	REC	DUPL	OID	ROW
07041	43.5 DEPTH	95.8%	94.6%			1
	8/13/90					
	near C-76-80					
	Depth is screen of					
	Hydropunch					
BL#01	METHOD BLANK	100%	97.0%			2

TOL-dB-S Toluene-DB(Surrogate (88-110))

4BrFB-S 4-Bromofluorobenzene(Surrogate (86-115))

# REPORT DOCUMENTATION PAGE

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6. AUTHOR(S) Stafford S. Cooper, Donald H. Douglas, Michael K. Sharp, Richard A. Olsen, Gregory D. Comes, Philip G. Malone					
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Engineer Waterways Experiment Station Geotechnical Laboratory 3909 Halls Ferry Road, Vicksburg, MS 39180-6199				8. PERFORMING ORGANIZATION REPORT NUMBER  Technical Report GL-93-30	
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13. ABSTRACT (Maximum 200 words)  At the request of the Naval Facilities Engineering Command (NAVFAC), Southern Division, Charleston, SC, the U.S. Army Engineer Waterways Experiment Station (WES) conducted the initial field trial of the Site Characterization and Analysis Penetrometer System (SCAPS) at Jacksonville Naval Air Station (NAS), Jacksonville FL. This work was carried out by a field crew consisting of personnel from WES and the Naval Ocean Systems Center during the period of 16 July 1990 to 14 August 1990.  The SCAPS investigation at the Jacksonville NAS has two primary objectives: (a) to provide data that could be useful in formulating remediation plans for the facility and (b) to provide for the initial field trial of the SCAPS currently under development by WES for the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), now the U.S. Army Environmental Center.  The original concepts for the SCAPS was to develop an integrated site screening characterization system whose capabilities would include (a) surface mapping, (b) geophysical surveys using magnetic, induced electromagnetic, and radar instruments, (c) measurements of soil strength, soil electrical resistivity, and laser-induced soil fluorometry (Continued)					
14. SUBJECT TERMS Cone penetrometer Laser induced fluorescence (LIF) POL contamination Site characterization and analysis penetrometer system (SCAPS)				15. NUMBER OF PAGES 143	
				16. PRICE CODE	
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13. (Concluded).

using screening instrumentation mounted in a soil penetrometer, (d) soil and fluid samplers, and (e) computerized data acquisition, interpretation, and visualization. The goal of the SCAPS program is to provide detailed, rapid, and cost-effective surface and subsurface data for input to site assessment/remediation efforts. Although a few system components had been previously field tested, this was the first field deployment of the full SCAPS with its unique fiber optic fluorescence detection tools.

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